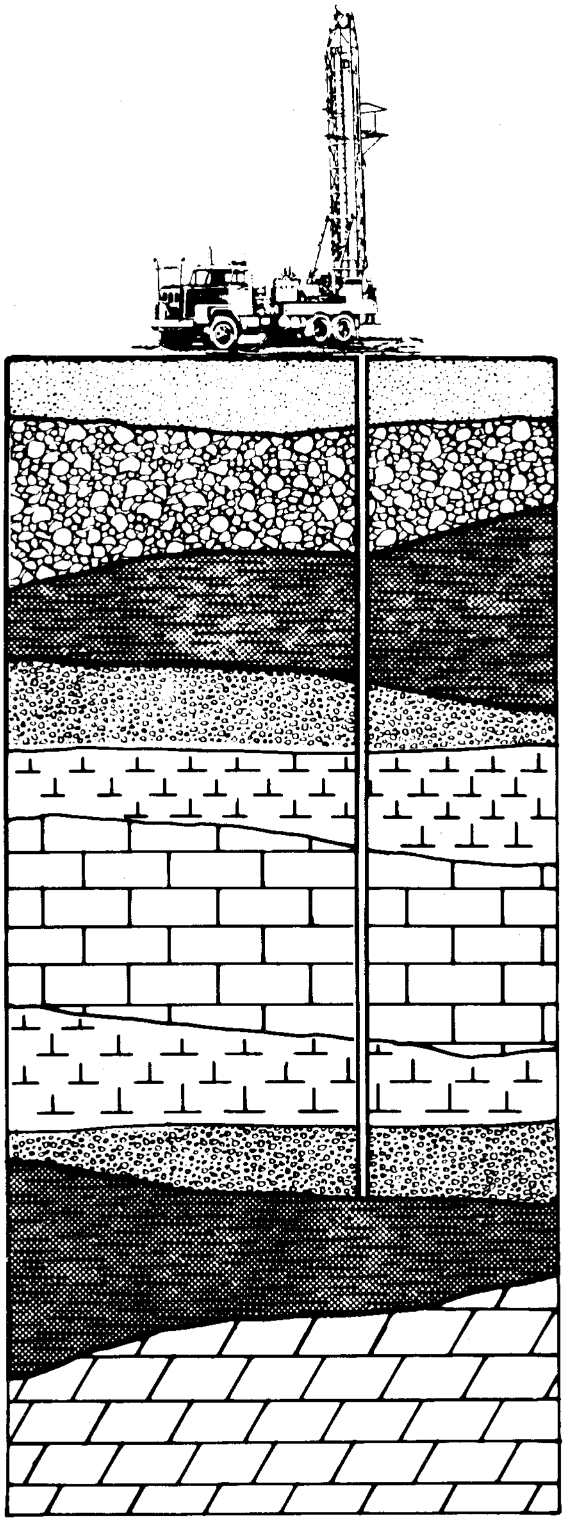


GROUNDWATER RESOURCES OF LOUDOUN COUNTY, VIRGINIA

by

J. Roy Murphy

NORTHERN REGIONAL OFFICE

COMMONWEALTH OF VIRGINIA

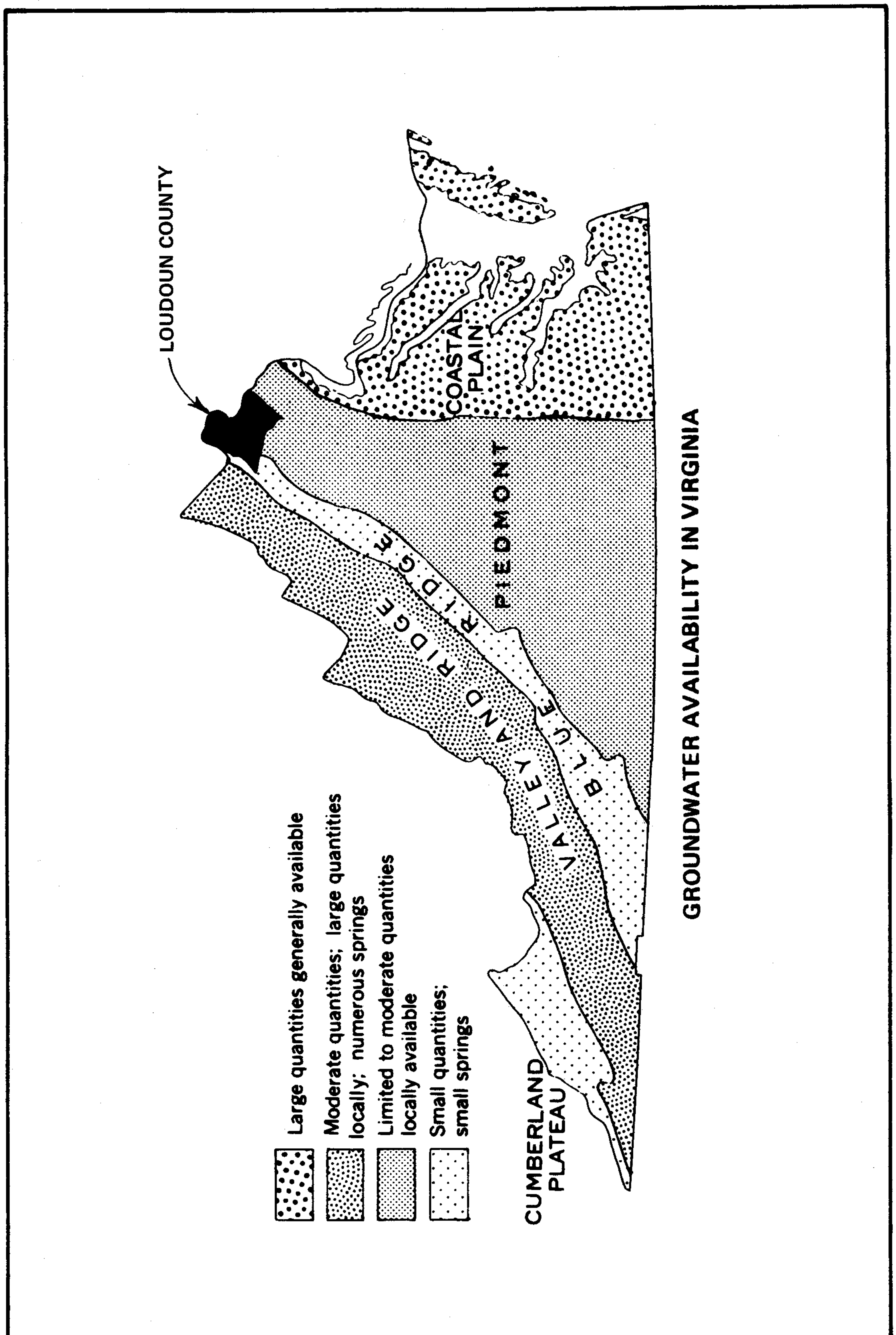
STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

Richmond, Virginia

Planning Bulletin 315

July 1979

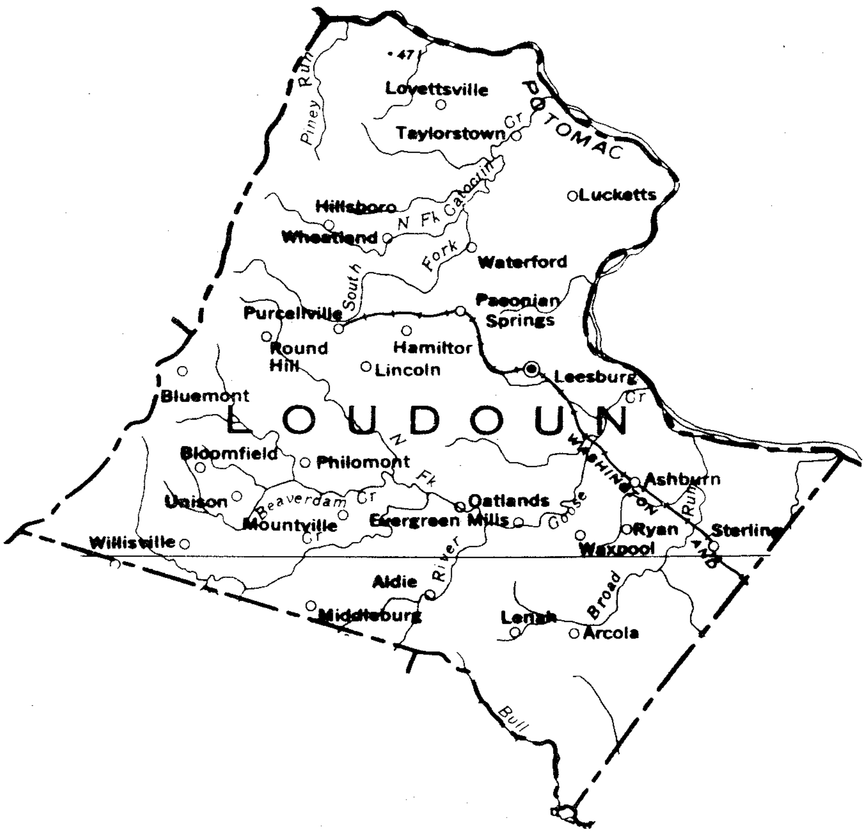


Source: Virginia State Water Control Board – BWCM

Frontispiece

LOUDOUN COUNTY GROUNDWATER

PRESENT CONDITIONS AND PROSPECTS



by
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VIRGINIA STATE WATER CONTROL BOARD
BUREAU OF WATER CONTROL MANAGEMENT

PLANNING BULLETIN 315

JULY 1979

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ACKNOWLEDGEMENTS

Appreciation is expressed to the citizens of Loudoun County who provided information to employees of the State Water Control Board on wells which they own and who allowed water samples to be taken. Also, officials of Leesburg, the County Health Department, AT&T and other agencies which supplied information are to be thanked. Particular thanks goes to those water well contractors who worked in Loudoun County and faithfully have rendered water well completion reports. Lastly the summer employees of the State Water Control Board, particularly Haywood A. Wigglesworth, who though temporary, rendered dedicated and vigilant service in sample collection, analysis, and data collection are to be praised.

FOREWARD

This preliminary report is part of a series intended ultimately to cover the Commonwealth. The purpose is to provide private citizens, groundwater users, developers, well drilling contractors, consultants, governments and other users with as complete a summary, as possible, of the groundwater situation, within the geologic constraints, in each county.

Using this report as a basic document, prospective groundwater users and other interested parties may form estimates of the potential occurrence of subsurface water. Any detailed studies or point-source studies should, of course, be performed by a trained geohydrologist. The State Water Control Board will be available as a public service organization to accumulate future data, act as source of general information and to perform a future update of the groundwater resources and quality. A glossary of terms is provided to aid those persons not familiar with the vocabulary of the geologic profession.

LOUDOUN COUNTY GROUNDWATER

PRESENT CONDITIONS AND PROSPECTS

by

J. R. Murphy

ABSTRACT

Groundwater is the end-product of geohydrologic conditions and depends on several variables. The greatest variable is the geology, followed closely by the topographic position. In Loudoun County the geologic units range in age from approximately 1.1 billion-year-old granites to 200 million-year-old lava materials.

The water-holding and subsequent yielding characteristics of a geologic unit are a result of the lithology and degree of tectonic deformation. These characteristics determine whether a rock unit is an aquifer (water-bearer) or aquitard (water-barrier) or aquifuge (unproductive). The areas of limestone conglomerate, sandstone, and other sedimentary rocks of the Triassic Basin are all fair-to-excellent producing units. The recent igneous rocks (diabase, etc.), on the other hand, tend to be poor producers, if at all. The areas containing the ancient plutonic and volcanic rocks yield the greatest quantities of water when fault structures are encountered; otherwise they tend to be dry. Other characteristics relevant to a unit's water-bearing potential are discussed in the text.

Data are presented in the text discussing hard and soft water regimes and specific chemical characteristics encountered in each groundwater province.

Pollution must be considered as a threat to continued use of groundwater. Such items as septic tanks, drainfields, buried fuel and chemical tanks, all have a potential for failure. Unlike surface waters, there is no easy, or inexpensive, way to flush the water table. Pollution, regardless of type, normally will stay until it is no longer dangerous. This pollution may last generations, not just years.

The U. S. Census Service estimates that there are approximately 5,000 wells in Loudoun County. Of this number, many are owned and have been used by towns, subdivisions, schools and industries. The majority, however, belong to individuals.

A map is included in this report that indicates the potential for groundwater as it presently is known. Indications are that the major fault zones, the Triassic sediments and the Potomac River margin possess the greatest potential for future groundwater development. Attention also is directed towards several areas wherein larger yields of water have been found than the regional averages would cause one to expect.

CHAPTER I

INTRODUCTION

Background

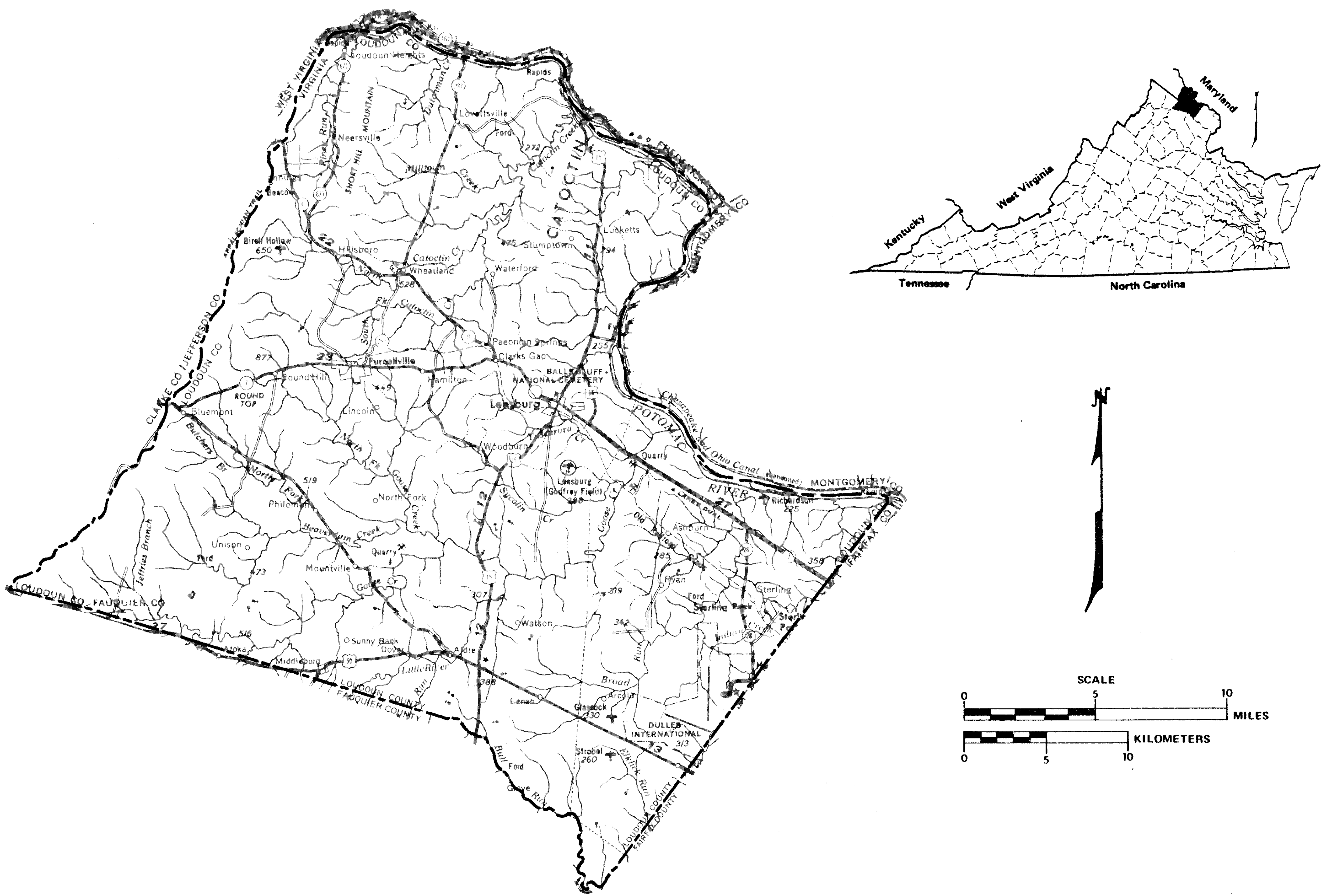
Loudoun County encompasses 1339 square kilometers (517 square miles) in area, located in the northern tip of Virginia (Plate 1). It occupies a part of economic region III as defined by the Virginia Division of Planning. The eastern edge of the county lies approximately 35 miles west of the nation's capital. The county is rural in nature, although about 35 percent of the population lives in urban areas. One-fourth of the people live in the eastern portion of the county, and slightly less than 50 percent of the employed workers commute outside of the county. The 1975 population was 48,900, with a 5.6 percent increase noted between 1970-74. The incorporated towns and their number of inhabitants (1974 data) are: Hillsboro (98), Leesburg (7000), Lovettsville (485), Middleburg (800), Purcellville (2000), and Round Hill (600). In addition, the planned communities of Sterling Park and Sugarland Run have, respectively, 13,600 and 5,500 persons. The population is expected to increase at a slower rate than previously, to 60,100 in 1980, and ultimately to 110,200 by the year 2000.

Presently about two-thirds of the total acreage of Loudoun County is in agricultural or open space useage. The number of large farms has continued to increase yearly, whereas the number of acres actually used for agriculture has declined. Statewide the county rated ninth (1970) in total value of all agricultural products, with 87 percent being livestock and related products. As a result of local government's efforts, several industries have moved into the southeast portion of the county around the Dulles Airport Complex. These industries include manufacturing and training. Other labor categories include, in order of the size of the labor force, Public Administration, Retail and Wholesale trade and Services, with smaller, but equal numbers in non-agricultural wage and salary, and Non-manufacturing (Data Summary, Loudoun County, 1975). Professionals make up almost 27 percent of the total labor force, with clerical specialties being second.

The increase in population, plus the change in the economic base, has produced a resultant change in housing patterns. Previously, prior to 1950, single dwellings on one-acre plots, or large plots with scattered apartments, were normal. The practices of today: to develop large apartment complexes and townhouses, plus subdivisions, have produced increased local demands on water-supply facilities.

In eastern Loudoun County most of the water is purchased from the City of Fairfax (Goose Creek Water System). This causes a problem. As the need for water increases, so does the price and the price of procurement. Groundwater already is a partial answer to this problem. The town of Hamilton obtains water from six wells. Leesburg utilizies six wells and a spring, whereas Middleburg only uses groundwater as a supplement to river supplies. Hillsboro, Purcellville, and Round Hill use springs and/or dam-reservoir combinations. The County Sanitation Authority is attempting to provide water to the unincorporated areas, although private sources also are used. Local industries frequently have drilled their own wells.

LOCATION MAP OF LOUDOUN COUNTY



Source: Virginia State Water Control Board — NRO

PLATE NO. 1

Surface water, spring, and dam combinations are usually better long-range solutions to water shortages, but they do cost more than groundwater systems and once exhausted cannot cheaply be replaced.

Purpose and Scope

The purpose of this report is to summarize available data concerning groundwater resources in Loudoun County and provide readers with a concise, though preliminary, booklet of the existing and potential groundwater conditions.

It is a harsh fact that man cannot live without potable water supplies. His life expectancy without it is limited to about three days, depending on environment and degree of exertion. Therefore, this report attempts to identify areas of undeveloped groundwater and present the quality of known supplies. Some problem areas will be outlined.

Methods of Investigation

It has been said by an unknown philosopher that, "All civilization exists at the indulgence of geology." The occurrence, availability and quality of groundwater are geology-dependent. Therefore, the geologic framework of the County was investigated from available reports and unpublished data. Information on the productivity of water wells was examined and consolidated with the geologic data to establish the correlation between geology and well yields. The influence of topography on well yields also was considered, as were the depths and construction characteristics of the wells. Chemical-quality samples were collected at selected sites to establish the effects of geology, and of man, on groundwater quality. These data were supplemented with chemical analyses from public water-supply wells, provided by the State Department of Health. Other sources of information on the hydrogeology of the county include data from water-level observation wells, water level measurements from private and public wells, pumpage records, pumping tests and other information provided by well drillers.

All water well information and records of water quality analyses used in this report are in the files of the State Water Control Board headquarters office in Richmond and the Northern Regional Office in Alexandria. These data have been computerized for storage and retrieval and were used to compile Appendices A and B.

Previous Investigations

The earliest mention of the geological conditions of Loudoun County is found in a metalurgical survey by Hotchkiss, published in 1884. During the next few years, several papers and classical studies were made, among these Rogers, (1884); Darton (1891); Geiger and Keith (1891); Keith (1893, 1894); Darton and Keith (1901) and Williams, Keith and Darton (1901). In 1923, two papers prepared by O. E. Meinzer began to relate to the groundwater situations. Many other geologic papers, too many to enumerate, were published before R. C. Cady released his Preliminary Report on Ground-water Resources of Northern Virginia in 1933. This was followed by the full report in 1938. In the 1950's a number of geology and related groundwater reports followed, written by Werner, Whitaker, and the Bloomers. P. M. Johnston published five reports on the geology and groundwater of the Washington area in the 1960's, which added further information applicable to the County. Other authors, Mack (1965), Toewe (1966, 1968) and Parker (1968), among them, wrote geology reports on portions of the county during the same period. The 1970's have seen the advent of geophysical data and much more detailed, localized reporting. The most recent report on a portion ofthe county is one by K. Y. Lee of the U. S. Geological Survey (1977). No one map or report, as yet, covers in detail all of Loudoun County. The State Geological Map prepared by the Division of Mineral Resources (1963) does present the entire county, but at a scale of 1:500,000. This map does not give sufficient detail for truly accurate ground-water studies. The map presented as Plate 5 is the product of combining many sources and is general in nature.

Water Well Numbering System

The water wells studied for this report are identified by the State Water Control Board's Bureau of Water Control Management well numbers. Each well number consists of two parts, such as 153-121. The first number, 153, denotes the County in which the well is located; in this case Loudoun County. The second number, 121, is a sequential number that refers to a specific well in Loudoun County.

CHAPTER II

PHYSICAL SETTING

Physiography

Loudoun County lies in two physiographic provinces, with the percentage in each being debatable. The western portion is part of the Blue Ridge Province, whereas the eastern part is in the Piedmont. The boundary was considered by Toewe, (1966) Fenneman, (1938) and Gathright (personal communication) as being on the fault line of the Bull Run Fault. This is identified as a line running north-northeast from near Aldie to a point near U. S. Highway 15 at the Potomac River. West of the fault line are found Precambrian and Cambrian-aged, crystalline rocks, layered volcanics and layered clastics. One thin unit of Ordovician limestone is also found west of the fault. East of the line exist Triassic-age rocks. Several other authors, among them Dietrich, (1970) and Espenshade, (1970) place the boundary in Loudoun County about two miles east of the West Virginia state border at the edge of the layered volcanic rocks near Bluemont. The writer of this publication prefers the placement of the line at the Bull Run Fault, with a further subdivision of the Blue Ridge Province into a Layered Clastics zone, a Layered Volcanics zone, and a Basement Complex zone (Gathright, personal communication). This arrangement is also more compatable with the groundwater discussion (Plate 2).

Elevations in the county range from a high in the western portion, two miles northeast of the Clarke-Fauquier-Loudoun county intersection, of 1920 feet above sea level, to 180 feet above sea level in the eastern portion. The elevation at the primary watergap in the Blue Ridge belt at Snickers Gap (Route 7) is 1080 feet. The area between the two elevation extremes is characterized, going west to east, by high ridges and gradually descending, rolling hills.

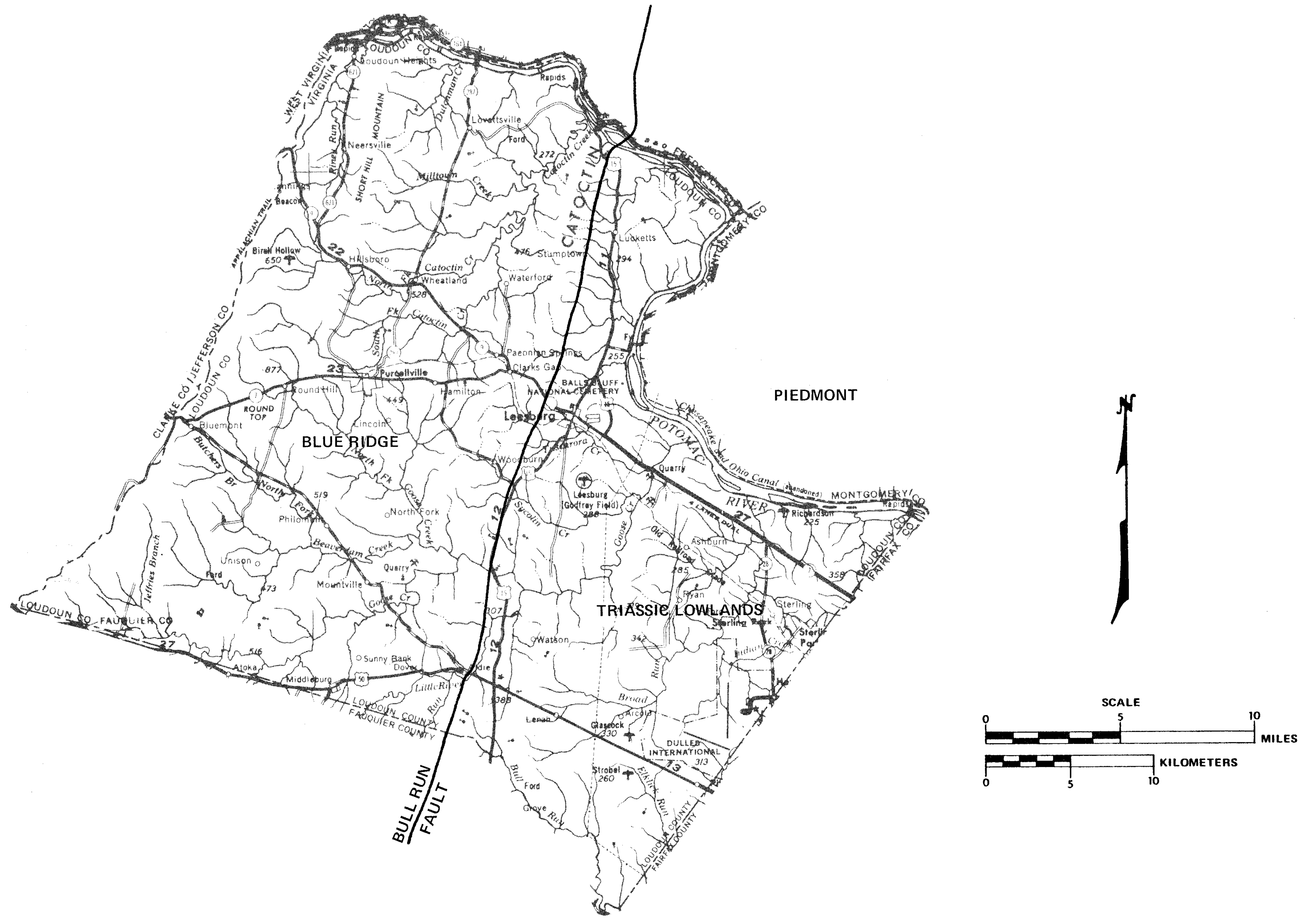
The entire eastern half of Loudoun County lies in the Triassic Lowlands, a subdivision of the Piedmont. This area is characterized by flat-to-gently-rolling topography with several prominent north-east-southeast-trending ridges. The maximum relief of the ridges is approximately 100 feet. The cause of the oriented ridges is two-fold, being tectonic and erosional in origin.

Hydrology

The Potomac River Basin contains all of Loudoun County, although the county is defined as part of sub-basin 11 by the Virginia Department of Conservation and Economic Development, Division of Water Resources. The county is subdivided further into seven watershed basins (Plate 3). It should be noted that the preponderance of water falling on these watersheds flows either directly to the Potomac River (north and northeast borders), or into Fairfax County to become part of the Occoquan system. Streams which are found in Loudoun County are the North and South Forks of Catoctin Creek, North and South Forks of Beaverdam Creek, Little River, Goose Creek, Piney Run and Broad Run.

Three streamflow gauging stations are maintained in Loudoun County. Two of these are located on Goose Creek, whereas the third is on Catoctin Creek. The data from these are published by the U. S. Geological Survey in "Water Resources Data for Virginia." Flow data

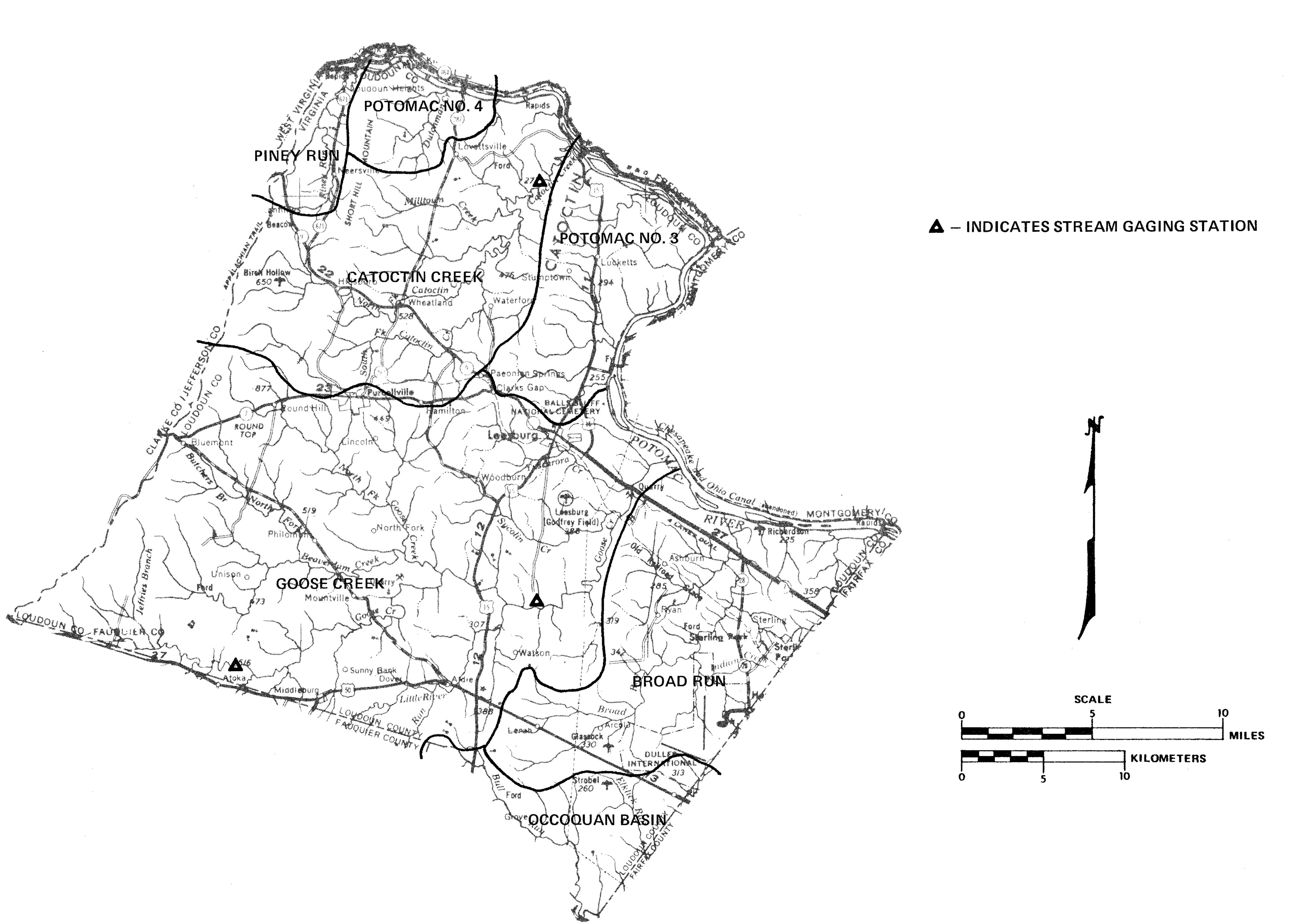
PHYSIOGRAPHY OF LOUDOUN COUNTY



Source: Virginia State Water Control Board – NRO

PLATE NO. 2

MAJOR WATERSHEDS OF LOUDOUN COUNTY



Source: Loudoun County Planning and Zoning Commission

PLATE NO. 3

from these stations for the fiscal years 1975, 1976, and 1977 are presented in Table 1.

Such data are of relevance, as the average discharge in cubic feet per second is related significantly to the drainage areas. The runoff of water from the watershed, translated into inches of water, can be compared to the rainfall for a similar period of time. Although the computations are complex, the runoff versus rainfall versus base flow also can be a gross indicator of the quantity of water available for recharge of the groundwater table. This recharge is, of course, not instantaneous but delayed due to the resistance of the media through which it moves. Other factors such as stream gradients, topography and soil types have strong effects on the recharge. See Plate 4 prepared by the Loudoun County office of the U. S. Department of Agriculture Soil Conservation Service.

The North Fork and South Fork of Catoctin Creek, Tuscarora Creek, Dry Mill Branch, Sycolin Creek, South Fork Sycolin Creek, Broad Run, Russell Branch, Beaverdam Run, Cabin Branch #1 and #2, South Fork Broad Run, and Sugarland Run were studied in detail for flood hazards by the U. S. Geological Survey, the Virginia Department of Highways and Transportation, the National Geodetic Survey, the U. S. Army Corps of Engineers, and the Division of State Planning and Community Affairs. The final report was presented in 1976 as a U. S. Department of Housing and Urban Development publication, Flood Insurance Study. The streams studied were perennial with distinct and variable channels. Broad Run and Sugarland Run are broad and flat, whereas the other channels are narrower and steeper. Although there

TABLE 1
LOUDOUN COUNTY
AVERAGE DISCHARGE AT MAIN RIVER GAGING STATIONS PER FISCAL YEAR

Station	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
1975												
1	15.6	15.5	30.2	11.4	15.0	138	112	120	201	102	107	69.0
2	37.4	30.0	51.3	15.2	21.9	269	140	176	327	131	132	73.8
3	85.5	74.9	141	48.3	62.1	908	402	484	844	395	372	193
1976 July 75 - June 76												
1	137	28.7	279	108	61.7	81.8	268	94.6	78.6	129	36.8	64.5
2	171	58.5	326	207	106	117	346	157	118	160	62.6	59.6
3	339	121	1005	510	267	308	985	393	315	468	146	161
1977 July 76 - June 77												
1	38.6	16.2	28.8	414.0	74.7	73.9	*---	**86.2	107.0	193.0	31.4	30.4
2	37.4	17.8	28.0	**272.1	122.0	128.0	111.0	127.0	159.0	170.0	44.9	16.4
3	130	54.1	84.7	*1715.0	288.0	286.0	98.5	151.0	416.0	485.0	115.0	48.2

* Readings biased upward by ice   ** Averages based on incomplete months

Station 1 - Catoctin Creek at Taylorstown, on right bank at upstream side of bridge on State Highway 663 (USGS No. 01638480)

Station 2 - Goose Creek near Middleburg, on right bank 250 feet upstream from bridge on State Highway 611 (USGS No. 01643700)

Station 3 - Goose Creek near Leesburg, on left bank 400 feet upstream from bridge on State Highway 621 (USGS No. 01644000) is little commercial, industrial or residential development in the floodplains, many roads and rail lines cross them. The cause of flooding in Loudoun County is almost entirely limited to local rainstorms and hurricanes. Large floods occurred in 1937, 1942, and 1972 (Tropical Storm Agnes). Thus far only one flood prevention lake has been formed; that being Chantilly Lake in the Broad Run watershed near Dulles Airport.

The aforementioned report presents data for predicted 10, 50, 100, and 500 year floods on all the mentioned streams. A presentation of the results of the flood study is beyond the bounds of this report. Detailed flood hazard maps are available of the Sycolin Creek, Tuscarora Creek, Broad Run - Sugarland Run areas, as noted in the bibliography.

Generally speaking, the quality of surface waters in Loudoun County is good, particularly the farther one is from the Potomac River. Catoctin Creek and Goose Creek are noted for good quality water. Even the Potomac, itself, in western Loudoun County, is fairly good. The quality of the lower Tuscarora, for the last 4.8 miles is poor. This latter condition is fairly true of most of the other streams; their quality degrades the nearer one goes toward the mouth. Water-borne sediment is also a problem in two areas of the County, with the Potomac #4 drainage area and Goose Creek basin losing up to 160 and 290 tons of soil material per square mile per year in 1968 (SWCB, Information Bull. 526, 1976).

<u>Climate</u>

The climate of Loudoun is judged to be temperate, with an average annual temperature range from -1°C to 23°C (30°F to 73°F). Normal temperature extremes are from -24°C to 42°C (-11°F to 107°F). The average annual rainfall is approximately 1.07 meters (42 inches) per year, although the year 1977 was exceptionally dry. The prevailing wind is from the southwest with seasonal winds from the northwest. Frequently the clash of the two air masses causing these winds produce heavy rains and subsequent flooding.

The tabulation presented below is taken from the Climatologic Data assembled by the National Oceanic and Atmospheric Administration for a period in excess of twenty years.

AVERAGE MONTHLY TEMPERATURE °C (°F)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0	2	7	13	18	22	24	24	20	14	8	2
(32.8)	(36.1)	(44.6)	(55.0)	(64.1)	(72.4)	(76.0)	(75.3)	(68.8)	(57.7)	(46.9)	(36.0)

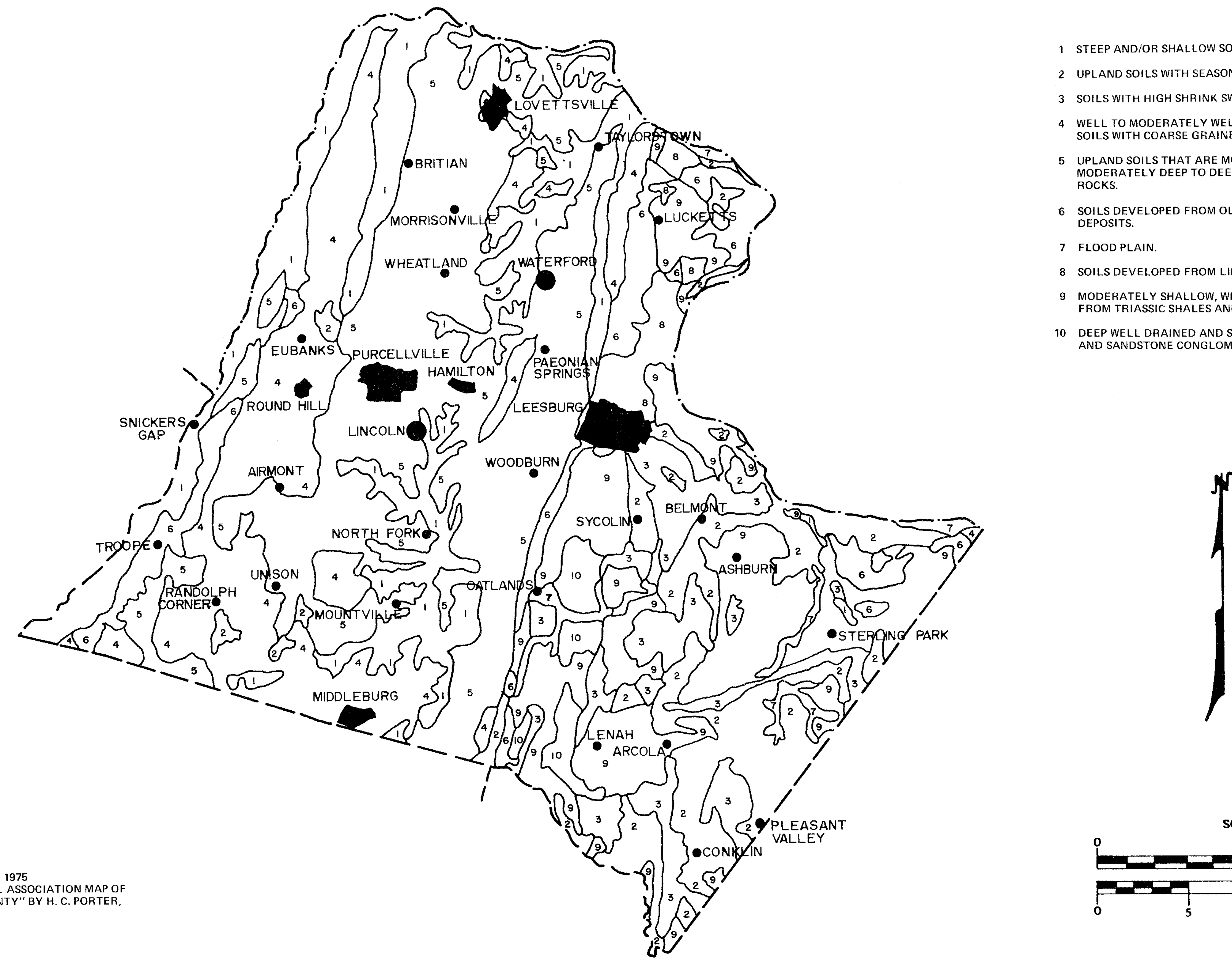
AVERAGE MONTHLY PRECIPITATION MILLIMETERS (INCHES)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
59.9	60.4	95.3	81.0	101.6	119.4	86.1	93.2	72.6	71.6	61.5	85.6
(2.36)	(2.38)	(3.75)	(3.19)	(4.00)	(4.70)	(3.39)	(3.67)	(2.86)	(2.82)	(2.42)	(3.37)

The recording station is located at Lincoln in west central Loudoun County. West of the station the winters are more severe and summers cooler than at the station. It should be noted that usually the hottest month is July, whereas the lowest temperatures are recorded in January. Further, the wettest month is normally June, with the driest months being the period September through November, and January through February.

Most groundwater is recharged during the fall and winter months

SOIL GROUPINGS IN LOUDOUN COUNTY



1 STEEP AND/OR SHALLOW SOILS FROM CRYSTALLINE ROCKS.

2 UPLAND SOILS WITH SEASONAL HIGH WATER TABLES.

3 SOILS WITH HIGH SHRINK SWELL TYPE CLAY SUBSOILS.

4 WELL TO MODERATELY WELL, DEEP TO MODERATELY DEEP UPLAND SOILS WITH COARSE GRAINED SAPOLITES FROM CRYSTALLINE ROCKS.

5 UPLAND SOILS THAT ARE MODERATELY WELL TO WELL DRAINED, MODERATELY DEEP TO DEEP, DERIVED FROM FINE GRAINED CRYSTALLINE ROCKS.

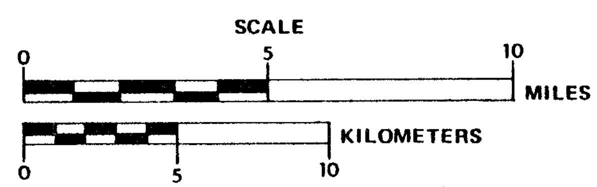
6 SOILS DEVELOPED FROM OLD ALLUVIAL, COLLUVIAL, AND FLUVIAL DEPOSITS.

7 FLOOD PLAIN.

8 SOILS DEVELOPED FROM LIMESTONE CONGLOMERATE.

9 MODERATELY SHALLOW, WELL TO MODERATELY WELL DRAINED SOILS FROM TRIASSIC SHALES AND FINE GRAINED SANDSTONE

10 DEEP WELL DRAINED AND SHALLOW STEEP SOILS FROM SANDSTONE AND SANDSTONE CONGLOMERATE.



BY: R. S. WEBER 1975
BASED ON "SOIL ASSOCIATION MAP OF LOUDOUN COUNTY" BY H. C. PORTER, JAN. 1952

Source: Virginia State Water Control Board

PLATE NO. 4

since vegetation utilizes the Spring and Summer rains. Previous severe droughts occurred in 1930-37, 1943-45, 1953-55, and 1964-65.

Soils

As noted in the Loudoun County Soil Survey, 1969, the soils of the county are divided into 55 series and also eight miscellaneous land types. Such a diversity is explained by quoting The Soils That Support Us. "First, there are those differences due to local variations in parent rock, slope and age. Secondly, there are those differences due to climate and vegetation. Then, there are some soils so young that no new features have developed, such as the fresh material just deposited by a stream, or the almost bare slopes of the mountains, or the dry, nearly sterile sand along the beach." (Kellogg, 1941).

Generally speaking, a given soil is divided into three zones: a surface horizon, a subsoil and a parent material zone. Another way of considering the soil is to think of three horizons overlying the rock, or parent material. Within these three basic horizons, and often overlying them, are other zones. Such a situation expressed graphically, for a mild temperate climate with moderate rainfall, would be as shown in Figure 1.

The A horizon is characterized by the chemical alternation of the soil material in acid, reducing environment. Clays of the kaolinite family, soluble carbonates and simisoluble iron minerals, if produced, are leached downward by moisture, leaving the horizon silica-rich. Therefore, the center portion of the zone is usually sandy and light colored. The upper portion is dark-colored from organic material.

<table>
<tr><th colspan="2">Horizon</th><th colspan="2">Description</th></tr>
<tr><td colspan="2">O</td><td colspan="2">Organic litter, humus</td></tr>
<tr><td rowspan="3">A</td><td>A_1</td><td>Organic Colloids & Minerals</td><td rowspan="3">Zone of leaching or eluviation</td></tr>
<tr><td>A_2</td><td>Light Colored leached</td></tr>
<tr><td>A_3</td><td>Leached, but transitional</td></tr>
<tr><td rowspan="3">B</td><td>B_1</td><td>Accumulation transitional</td><td rowspan="3">Zone of accumulation or illuviation</td></tr>
<tr><td>B_2</td><td>Accumulation, clay formation, deep color</td></tr>
<tr><td>B_3</td><td>Transition, more color than C, carbonate accumulation</td></tr>
<tr><td colspan="2">C</td><td colspan="2">Silcia, Carbonate, Sulfate accumulation, slight weathering</td></tr>
<tr><td colspan="2">D or R</td><td colspan="2">No Alternation</td></tr>
</table>

Figure 1 Idealized Soil Profile in a region of mild temperature and moderate rainfall. (After Sowers & Sowers, 1970)

The B horizon is thicker than A and contains an accumulation of clay materials, iron, and carbonates. The B_1 layer can be partially cemented and deeply colored, whereas the B_3 layer is lighter in color.

Below the two true soil horizons is the C layer of slightly weathered, or crumbly bedrock. If an ancient, unrelated soil, a paleosoil, is present, it is called the R horizon; otherwise the base layer, if rock, is the parent material, D.

According to recent thinking there are in Loudoun County ten major groupings based on major, similar, soil properties. These have features affecting both urban and rural use. It is stressed that the coding indicating certain properties is not all inclusive and does not apply to each individual soil mapped within an association. That is the type of detailed information which should be obtained from the detailed soils maps for a given tract.

The ten soil groupings are listed in Table 2 and briefly described.

It is not the purpose of this publication to describe and define all the soils of Loudoun County. Such data is available in the Soil Survey series 1951, no. 8, issued September 1960 by the U. S. Department of Agriculture. This publication and other more recent ones are available through the local Soil Conservation Service office.

The primary purpose for mentioning the soils is that survey publications contain detailed cross-sections of all the soils within the county. These cross-sections provide data on the thickness of the soil layers and the internal-drainage characteristics. These are an important factor in water-well productivity, particularly in areas underlain by crystalline bedrock. The internal drainage characteristics affect the rate at which water infiltrates the soil and gives an indication of the recharge rates. Soil texture is the major determining factor affecting internal drainage. A coarse-

TABLE 2

LOUDOUN COUNTY

SOIL GROUPINGS

Soil Group & Name	Physical Characteristics	Water-bearing Characteristics for Overburden Wells
I Steep & shallow soils from crystalline rocks	Found on steep slopes Thin soils Many rock outcrops	Locally productive immediately over bedrock Not dependable
II Upland soils with seasonal high water tables	Water table highest from January to April Most found in Triassic Lowland	Locally productive for shallow wells Easily contaminated
III Soils with high shrink-swell clay subsoils	Usually overlie diabase and basaltic rocks of the Triassic Lowland	Well yields would be seasonally controlled
IV Deep upland soils with coarse-grained saprolites from crystalline rocks	Located in western-most Piedmont Uplands and Middleburg Overlie mostly basaltic-type rocks	Usually reliable for single-family dwellings Good recharge potential
V Upland soils from fine-grained crystalline rocks	Largest single unit overlying crystalline rocks, mostly granitic-types with minor greenstone. Highly variable in depth, clay content and grainsize	Variable characteristics prevent any overall predictions

TABLE 2 (cont.)

LOUDOUN COUNTY

SOIL GROUPINGS

Soil Group & Name		Physical Characteristics	Water-bearing Characteristics for Overburden Wells
VI	Alluvial, Colluvial, and Fluvial Soils	Found at the base of mountains particularly Lovettsville and Lucketts areas Usually coarse, cobbly deposits, but can contain clay lens	Water usually passes quickly to lower depths or remains as a local reservoir perched on a clay bed
VII	Flood Plain Soils	Highly variable composition though usually contains silt and clay size material mixed with rock beds	Generally productive, however restricted by Flood Plain Insurance Regulation
VIII	Soils from limestone Conglomerate	Very complex and frequently overlie sinkholes	Surface wells not usually feasible
IX	Moderately shallow fairly well drained soils of Triassic Clastics	Mostly wide-spread soil of Triassic Basin overlies shale and fine grained sandstone Usually less than 660 mm (26 ft) thick	Not practical for shallow wells
X	Deep well drained and shallow steep soils of Triassic conglomerates	Characterized as cobbly and possessing rapid internal drainage Limited to areas northeast and southeast of Oatlands	Well production would be most dependable at soil-rock interface

textured soil will retain and recharge water more rapidly than a fine-textured clay, or clay loam. An additional benefit of the official soil survey publication is the engineering chart, which summarizes the texture, permeability, depth to bedrock, depth to water table and other characteristics.

Vegetation

At present only about 16 percent of the land remains in forests. Little of this is virgin growth. The predominant timber is hardwood, consisting of oak, hickory, maple, beech, yellow poplar, black locust, walnut, sassafras, dogwood, and persimmon. Weeds and deliberate pasture plants grow generally well. Additionally, the bushes and shrubs of the forest areas are fairly prolific. Needless to say, vegetated areas act as better watershed and recharge zones than do highways and urban zones.

CHAPTER III

HYDROGEOLOGY

Geological Setting

Occupying, as it does, two physiographic provinces composed of four sub-provinces, the geology of Loudoun County is very diverse and complex. Therefore, the hydrologic system developed on and by the geology is not simple. The original geologic units frequently have been altered by weathering, tectonics, vegetation and land use. The rocks and rock materials, themselves, are assigned to three basic groups based upon origin. The three origins are sedimentation, igneous emplacement, and metamorphic processes. This gives rise to the groups - sedimentary, igneous, and metamorphic rocks (Plate 5).

The oldest rocks found in the county are the granite and granite-like rocks of the Marshall Formation and granulite gneiss to the Southwest. Though granite-like all these rocks are gneissic in nature. Above this group are other metamorphic rocks of sedimentary origin. These rocks include sandstones, boulder beds, conglomerates and recrystallized limestone. Above this complex were deposited many layers of basaltic lava flows. These also have been metamorphosed, with three easily recognized facies being present.

The metabasalt, called the Catoctin Formation, covers a wide area of the county and is the primary ridge-former of the Blue Ridge Mountains. Overlying the Catoctin is a narrow belt of up to 500 feet-thick quartzites, interbedded phyllites and cross-bedded conglomerates.

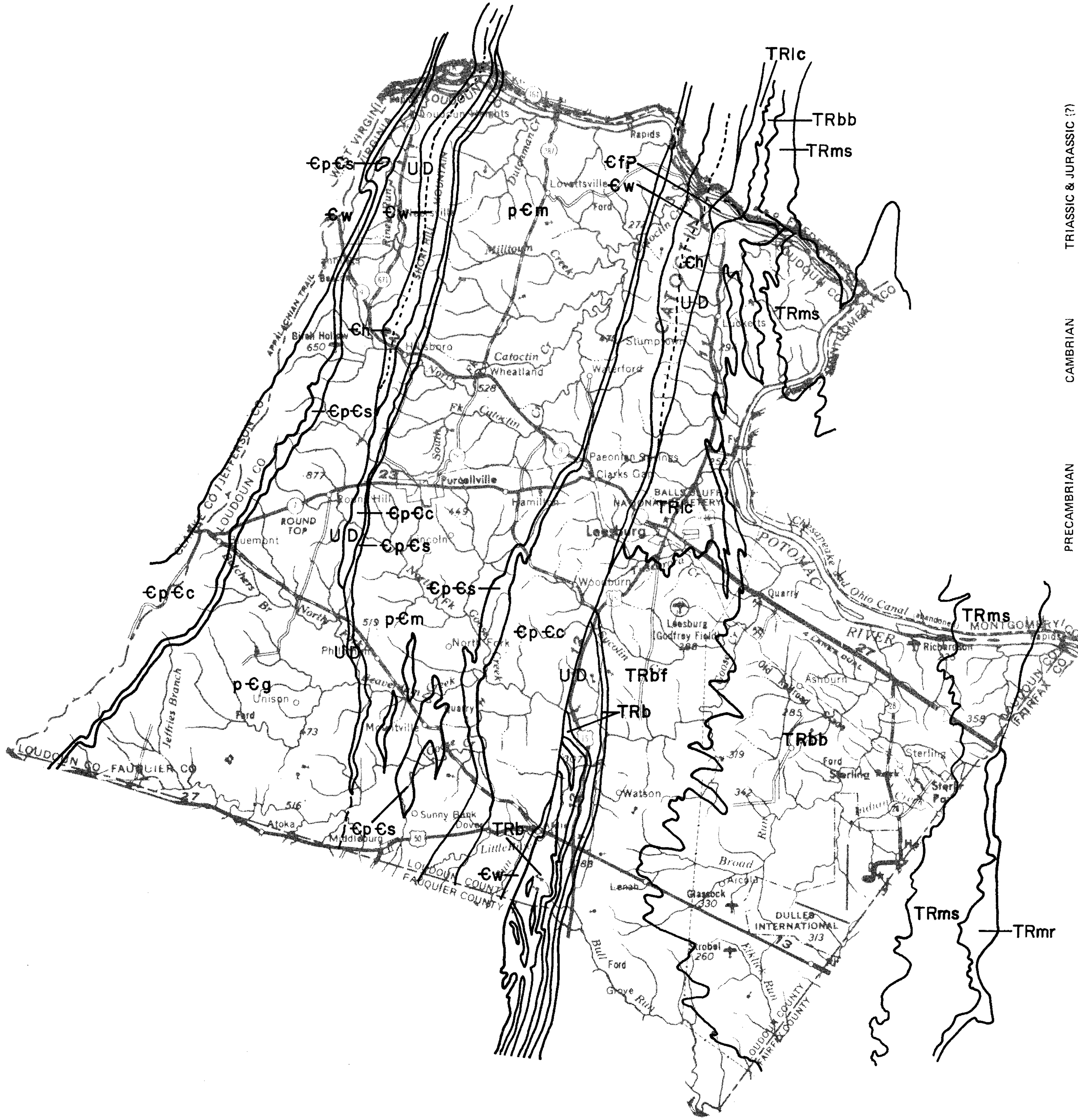
Throughout most of the county, the Bull Run fault marks an abrupt change from Cambrian (?) age, 570 M.Y.B.P., to Triassic age 190-225 M.Y.B.P., sedimentary rocks. However, in the extreme north central and south central portions of the county wedges of metamorphic rock border the lowest edge of the fault. Both of these wedges, approximately 122-152 meters (440-500 feet) wide at the widest points, taper to zero several miles short of the Washington and Old Dominion Railroad tracks west of Leesburg.

The northern wedge contains metamorphosed sediments of the Hampton (Harpers) Formation and the Erwin (Antietam) Formation of quartzite and silty phyllite. The southern wedge, on the other hand, is almost entirely quartzite of the Weverton Formation, with a very thin band of Loudoun Formation phyllite on the west (Gathright, personal communication).

As stated previously, the Bull Run fault forms the physiographic boundary and marks the western border of the Triassic lowlands portion of the Piedmont Province (Plate 2). It is thought that the fault has a vertical displacement of as much as 3048 meters (10,000 feet) with the eastern block being downthrown (Parker, 1968). This block is comprised of sedimentary rocks which have locally been intruded by igneous rocks. The sedimentary rocks are grouped into four basic types: conglomerate, both limestone and quartz; sandstone; shale or siltstone; and pyroclastic rock.

Several theories have been put forth to explain the origin and subsequent geologic history of the Blue Ridge - Piedmont section of the United States. But regardless of theory, there are only a few places where stratigraphic units can be correlated from one side of the Blue Ridge to the other. Thus, establishing a correlation between

GENERALIZED GEOLOGIC MAP OF LOUDOUN COUNTY



EXPLANATION

TRIASSIC & JURASSIC (?)

BULLRUN FORMATION
- TRb BASALTIC – FLOW BEARING CLASTICS MEMBER
- TRlc LEESBURG LIMESTONE CONGLOMERATE MEMBER
- TRbf MIXED CLASTICS

- TRbb BALLS BLUFF SILTSTONE

MANASSAS SILTSTONE
- TRms MANASSAS SANDSTONE, SANDSTONE MEMBER
- TRmr RESTON MEMBER, MANASSAS SANDSTONE

CAMBRIAN
- €f? ORDOVICIAN – CAMBRIAN FREDERICK (?) LIMESTONE
- €er ERWIN (ANTIETAM) FORMATION – NOT SHOWN
- € h HAMPTON (HARPERS) FORMATION
- € w WEVERTON FORMATION
- € l LOUDOUN FORMATION (?)

PRECAMBRIAN
- € p-€ c CATOCTIN FORMATION
- € p lm EVERONA FORMATION (?)
- € p-€ s SWIFT RUN FORMATION
- p-€ g GRANULITE GNEISS (UNDEFINED)
- p-€ m MARSHALL FORMATION – FELSIC GNEISS

U/D FAULT TRACE
DASHED WHERE APPROXIMATE, DOTTED WHERE COVERED OR INFERRED. U, UPTHROWN BLOCK; D, DOWNTHROWN BLOCK.

CONTACT LINE
BETWEEN ROCK UNITS.
SOLID WHERE KNOWN,
DOTTED WHERE COVERED OR UNPROVEN.

N

SCALE

0 5 10 MILES

0 5 10 KILOMETERS

Source: USGS, VDMR and VSWCB – NRO

PLATE NO. 5

the well-known miogeosynclinal rocks west of the Blue Ridge with the very-poorly-known eugeosynclinal (?) rocks of the Piedmont has become a major problem in Appalachian geology studies.

Some authors feel that the Blue Ridge occupies the site of a welt, or "median geanticline", that persisted throughout nearly 300 million years (Reed, 1970). Related to this idea, Drake, Ewing, and Sutton proposed, in 1959, that the Blue Ridge, deeply buried at the time, was the dividing zone for two separate basins of sedimentary deposition; the western basin being a shallow shelf trough, while the eastern trough was deep receiving potentially over 6100 meters (20,000 feet) of material. Basement uplift later exposed the entire eastern continental margin to erosion and produced today's Blue Ridge.

Others authors, notably Dewey and Bird (1970a, 1970b) say that the Blue Ridge, being basaltic rock, represents the site of upwelled, oceanic crust material caused by continental collision. The collision in this case was between the North American and African plates. Thus the Piedmont Province is really a residual portion of the African continental glued onto the North American continent.

In any event, the oldest rocks, the granitic gneisses, are thought to be 1000 to 1100 million years old. These rocks were uplifted, exposed to erosion, and locally overlain with variable thickness of boulders and sediments.

Beginning in late Precambrian time lavas and tuffs of the Catoctin system were deposited over the basement rock and local sediments. Further sediments were deposited between the lava flows.

Feeder dikes and sills of gabbro penetrated underlying rocks at this time (Brown, 1970).

The weight of the load of sediments caused subsidence in the eastern trough and to a lesser extent the western trough. Some local uplift took place of sufficient duration for a soil to form before reburial; thus producing in local areas the Loudoun Formation. Above the Catoctin Formation, and local Loudoun, next was deposited the quartz sand of the present Weverton Formation, followed by mud, silt, and sand forming the upper Weverton and Hampton (Harpers) Formations. The last-recorded period of deposition was the sandy material of the Erwin (Antietam) Formation. If any later deposition took place, it has been removed by later erosion.

In later Paleozoic time, horizontal forces from the southeast (continental collision ?) produced compressional strain in the rock units. More competent rocks were fractured and faulted, while less competent rocks flowed. The forces also caused metamorphism by heat and pressure, which changed many of the sedimentary units: i.e., sand, limestone, silt, etc., into quartzite, marble, and slate respectively.

During Triassic time, normal tension faults developed, with down-dropping on the east side. Associated with this cracking due to tensional stress, more igneous material, mostly basaltic in nature, was emplaced. The ancestral Triassic Basin, to the east of Bull Run fault, began receiving clastic sediments. The granites were formed by deep intrusion of molten rock into already-established beds. These subsequently have been exposed by heavy erosion. Such erosional forces are still at work producing the landforms of today.

Geologic Formations

A simplified geologic map of Loudoun County is shown in Plate 5. Table 3 lists the rock formations. It should be noted that the column begins with the oldest at the bottom and becomes younger upward; in the order that the rocks would be encountered by a driller. The water-bearing properties have also been noted in general terms. The exact age relationships are also indefinite in some cases, as much more geologic work is needed. A discussion of the groundwater characteristics of the formations according to lithology and physiographic province is presented further in the text.

The Marshall Formation is the oldest recognizable unit in the study area. The unit has been called the Basement Complex (Bloomer and Werner, 1955), Virginia Blue Ridge Complex (Brown, 1958) and various formational names. These rocks are found in a wide belt 5.6-10.5 kilometers (3.5-6.5 miles) wide in the western half of the county, bounded on both sides by the Catoctin Greenstone. Several types of intermediate and granitic gneisses are widespread in the belt. These generally are considered by the geologic profession to have been of igneous origin, later metamorphosed. Some authors have reported what they believe to be rocks of sedimentary origin intruded by granites (Jonas and Stose, 1939). Parker (1968) considered the eastern side of the belt as being the shallower edge of the Marshall and reported it as being characterized by smaller crystal sizes. In the western, deeper side, he reported feldspar phenocrysts up to 50 millimeters (2 inches) across. The coarser texture and different associated minerals, i.e. garnets and biotite, suggests a higher grade of metamorphism for the western edge. An extensive quartz vein

TABLE 3

LOUDOUN COUNTY

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Age (Geologic Period)	Rock Unit and Symbol[1]	Physiographic Occurrence	Lithology	Water-Bearing Properties
Triassic	Diabase (basalt) (TRB)	Triassic Lowlands	Dark, blue-grey-to-black igneous rock midway between basalt and gabbro in grain texture.	very poor aquifer, dry holes common.
Triassic	Newark Group (TRLC) (TRBF) (TRBB) (TRMS) (TRMR)	Triassic	Conglomerate, sandstone, shale, basalt pyroclastics and zones of contact metamorphism. Most sedimentary units are red in color. Large local deposits of limestone conglomerate around Leesburg.	very good aquifers; deep drilling (in excess of 500 ft.) feasible; best wells usually less deep.
Ordovician - Cambrian	Frederick Limestone (€F?)	Layered Clastics	Blue slaty, crystalline limestone	Good water bearing units at depths less than 400 feet.

TABLE 3 cont.

LOUDOUN COUNTY

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Age (Geologic Period)	Rock Unit and Symbol[1]	Physiographic Occurrence	Lithology	Water-Bearing Properties
Cambrian	Erwin (Antietam) (€ER)	Formation Layered Clastics	Predominately an interbedded sequence of white, fine-grained quartzite with minor darker phyllites or sericitic quartzite.	Generally not water-bearing unless faulted.
Cambrian	Hampton (Harpers) Formation (€H)	Layered Clastics	Light grey to greenish-grey phyllite inter-bedded with layers of fine-grained quartzite, locally calcareous, some graywacke and medium to thick-bedded, coarse-grained quartz sandstone.	Generally a low water producer requiring inter-mediate depth wells - 200-400 ft.
Cambrian	Weverton Formation (€W)	Layered Clastics	Light grey-to-white, fine-grained, finely-laminated-to-bonded quartzite. Some quartz-pebble conglom-erate, pebbly quartz sandstone, and very sericitic sandstone, phyllite and sandy phyllite.	Poor aquifer

TABLE 3 cont.

LOUDOUN COUNTY

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Age (Geologic Period)	Rock Unit and Symbol[1]	Physiographic Occurrence	Lithology	Water-Bearing Properties
Cambrian	Loudoun Formation (?) (€L)	Layered Clastics	Light-purple, tuffaceous phyllites, unit is not mappable, discontinued as a stratigraphic term. (Gathright and Nystrom, 1974, p. 15) (not shown on map)	Only locally occurring, generally poor.
Upper Pre-Cambrian	Catoctin Formation (CPCC)	Layered Volcanics	Interbedded, reddish-purple, tuffaceous phyllite; dark-green metabasalt; white, pink and tan rhyolitic metatuff, epidotized quartzose meta-sediments; metabasalt, basaltic flow breccias, epidosite and purple amygdaloidal slate.	Generally considered poor water-bearing. Yield and depth in the low (shallow) to moderate range.
Upper Pre-Cambrian	Everona (?) Formation	Layered Clastics	Discontinous, beds of shallow, massive-to-medium-bedded, white, blue, gray, green, dull-to-poorly-lustered marble. (not shown on map)	Generally poor aquifer due to shallowness.

TABLE 3 cont.

LOUDOUN COUNTY

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Age (Geologic Period	Rock Unit and Symbol[1]	Physiographic Occurrence	Lithology	Water-Bearing Properties
Upper Pre-Cambrian	Swift Run Formation (CPCS)	Layered Clastics	Heterogenous unit of metagraywacke, meta-arkose, and phyllites. Overall texture ranges from gneissic boulder beds upward through cobble beds and arkoses to cross-bedded, medium-grained arkose and platy-bedded sandstone.	Generally good for slow demand use.
Pre-Cambrian	Marshall Formation (PCM) (PCG)	Basement Complex	Light-to-dark gray, medium-grained granitic rock, including quartz monzonite syenitic granite and augen gneiss. Felsic and mafic dike intrusions.	Dependable aquifer at depths less than 200 ft. but only moderate quantity of water.

1 Symbols correspond to aquifer listing in Appendix B

Sources: Cady (1938); Toewe (1966); DeKay in Lukert and Nuckols (1974); Gathright and Nystrom (1974); Mack (1965); Parker (1968); and Virginia State Water Control Board - NRO system occurs on the eastern half and leaves masses of blue quartz when weathered.

In the case of a eroded anticline, such as the Blue Ridge area, the rock units decrease in age from the core outward. Thus, the next unit encountered on each side of the Marshall Formation is the Swift Run and Catoctin Formations, depending on local conditions. Late Precambrian erosion of the gneissic and grantic basement rocks produced a relief of several hundred feet. Into these drainage features were deposited boulders and cobbles of the basement rocks, intermingled with finer mineral products of mass-wasting. The depositional pattern was discontinuous, yielding here some deep beds of one type rock and in other areas shallower beds. The rock types grade upward from boulder beds to cobble-conglomerate to coarse-grained arkose and platy-bedded, fine-grained feldspar-bearing sandstone. The beds are often lenticular and of limited lateral extent. Sericite and quartz form 65-90 percent of the groundmass. Other minerals such as chlorite, epidote, and iron compounds occur locally.

At the top of the phyllitic arkoses, where they grade into phyllites, there are zones of bluish-white, recrystallized limestone (marble) lenses, typically shallow in depth and up to 30 meters (100 feet) long (Parker, 1968). These were called the Everona Formation by Tinsely Mack in 1965. They appear to be enclosed in the upper beds of the Swift Run Formation. Their thickness ranges from 4 to 29 meters (14 to 95 feet), whereas the colors and textures range from white, gray, light blue, and light green, with fine to medium crystals. Some talc, graphite and mica occur as impurities in individual outcrops. Recent work has determined that the limestone of this type found in Loudoun County are not typical of the Everona, therefore suggesting the use of the (?) after the term (Gathright, personal communication).

The bulk of the western half of Loudoun County is composed of two bands, the eastern being the wider, of the Catoctin Formation. This unit is composed almost completely of greenschist-facies, metamorphosed, basaltic rock. The most typical form is a dark-gray-to-blackish-green, massive, lava flow with fractures. A pistachio-green, epidosite form is the next most common form. The third variety is a chloritic phyllite which apparently marks zones of maximum stress-relief during diastrophism (Parker, 1968). Between the flows are found beds of phyllites, rhyolitic metatuff and metasediments, and purple slates. The latter in an amygdaloidal form was previously called the Loudoun Formation.

The next three rock units are lumped together as the Chilhowee Group and are detrital marine sediments which have undergone low-grade metamorphism. The lowest unit, approximately 137-183 meters thick (450-600 feet), is the Weverton Formation. The formation occupies a position along the West Virginia border of Loudoun County and another linear slice adjacent to the Bull Run Fault. The most common constituent of the Weverton is a quartzite, with lesser quantities of phyllite, quartz pebble conglomerate, sandstone, and sandy phyllite. Generally, the quartzite is impermeable.

Stratigraphically above the Weverton Formation is the Hampton (Harpers) Formation of laminated-to-thick-bedded, dark-grayish-green, very-fine-grained, phyllitic, feldspathic graywacke with ledge-forming, medium-to-thick-bedded, coarse-grained quartz sandstone and quartzite.

The unit is reported to be up to 61 meters (200 feet) thick west of the Bull Run Fault.

Continuing upward from the Hampton Formation is found the Erwin (Antietam) Formation of white, fine-grained quartzite, silty phyllite, and sericitic quartzite. From the Potomac River the unit extends southwestward for about 7.2 kilometers (4.5 miles) before tapering downward into the Bull Run Fault.

About 2.4 to 3.2 kilometers (1 1/2 to 2 miles) north of Lucketts and west of the fault a small mass of lower Ordovician Frederick limestone is found (Cady, 1938). This thin exposure consists of a blue, slaty, crystalline limestone. The depth of the formation is thought to be between 30-61 meters (100-200 feet). Although called Ordovician in age by Cady, the Virginia Division of Mineral Resources has labeled it as Cambrian. This is the reason for the question mark in the Explanation of the geologic map.

The Newark Group comprises the suite of sedimentary rocks, Triassic in age, which lies east of the Bull Run Fault and comprises almost the entire half of Loudoun County. The Group has been divided by K. Y. Lee (United States Geological Survey, 1977) into the Manassas Sandstone, Balls Bluff Siltstone and Bull Run Formation. The Manassas has a Reston member and a sandstone member. The Bull Run is also further divided into the Leesburg Limestone Conglomerate member and Basaltic-flow bearing clastics member (Plate 5). These rocks, predominately red to maroon in color, include conglomerates, sandstone, siltstone, and shale. All the various units are interbedded vertically and interfinger laterally. Additionally, several large bodies of igneous rock, primarily diabase (bluestone), have been injected into the sedimentary units. Other igneous rocks noted are syenite and basalt. The syenite resembles granite, but lacks the normal quartz content. Most of the igneous rocks are found as dikes, sills or stocks, although many lava flows and volcanic ash deposits are also present.

The limestone conglomerate outcrops west of Leesburg in a large north-south trending deposit. It interfingers with sandstone, shale and pyroclastics south and east of Leesburg. The limestone pebbles are from 6.35 millimeters (0.25 inches) up to several feet in diameter, all in a red matrix of quartz, feldspar, calcite, mica, chlorite, and clay (Toewe, 1966). The majority of pebbles are calcite or dolomite, whereas about 25 percent are quartz, and the remainder meta-basalt, schist, feldspar, phyllite, and shale pebbles.

The quartz conglomerate is exposed throughout a large portion of the Southern part of the county, particularly around Leesburg. Here the pebbles are 45-55 percent quartzitic material, 6.35 millimeters (0.25 inches) to 152 millimeters (6.0 inches) in diameter. Such deposits are up to 183 meters (600 feet) in thickness.

The shales and sandstones owe their color to varied proportions of iron oxide, both as a constituent and as grain coatings. The shales range from soft to extremely brittle. The sandstones frequently contain high enough proportions of feldspar to be counted as an arkose. Colors noted are pink, gray, red, maroon, brown, and green. Grain textures range from medium to coarse. The Manassas and Bull Run units represent fan-shaped river or stream deposits, whereas the Balls Bluff was deposited chiefly in lakes. It should be mentioned that the latter beds of siltstone are frequently calcareous.

In the area between Arcola and Conklin and along Virginia routes 659 and 772 there are several zones of "baked" shale. This dark, dense rock, called hornfels, forms adjacent to igneous intrusions where country rock is cooked by the high temperatures. The metamorphosed rock may resemble a basalt. The zone of affected rock can extend up to 0.8 kilometer (0.5 mile) from the intrusion and exhibit transitional metamorphism from heat source outward.

Geologic Structure

In the most simplified terms the structural geology of Loudoun County may be thought of as a large, eroded, upward-arched fold of rocks (western part), bounded by a deep normal fault and flanked to the east by a large basin of sedimentary, igneous and volcanic debris-origin rocks. The regional trend of all the structures is close to N20^{o}E.

The Blue Ridge portion of the county may be thought of as one large upwarp of the earth's material 12.9 kilometers (8 miles) wide upon which smaller folds 20 meters to 200 meters (66 to 650 feet) were superimposed. There were several periods in geologic history when strong horizontal, compressive forces further upwarped the surface and exposed the whole area to erosion.

The Triassic Basin, part of the larger Culpeper Basin, was uplifted at its northern end and downwarped in the south. It was later tilted westward and north and downdropped along the Bull Run fault. The diabase intrusions occurred during the dropping (Lee, 1976). The Bull Run Fault, itself, extends north and south out of Loudoun County into Maryland and southern Orange County, respectively, a distance in excess of 145 kilometers (90 miles). The fault-plane dips southeast at on an angle of 30^{0}-50^{0} (Keith, 1893). Other normal faults are also present in the county, but most are roughly perpendicular to the Bull Run. Most of these occurred after the diabase intrusions.

The tectonic forces to which the area was exposed also caused the regional joint system. Three joint sets are evident in the Triassic sedimentary deposits. Predominately these are east-west, nearly vertical to vertical, and N50^{0}E, with dips 70^{0}SE to vertical. In the rocks on the west side of the fault the dominant joint sets are N10^{0}S, N80^{0}E, and N45^{0}W, with all dips being nearly vertical. Such joints can be the sites for small-volume water supplies.

The basin sediments are thicker on the west side and thin-to-a-feather-edge on the east. The angle of inclination is 15^{0}-20^{0} to the northwest, with the greatest dips in the west.

Groundwater

Groundwater is an integral part of the earth's water circulation system, which is called the hydrologic cycle (Plate 6). Groundwater originates from precipitation in the form of rainfall or melting snow. That portion of the precipitation available to groundwater recharge is equal to the total precipitation minus evaporation, transpiration by growing plants, runoff to streams, and the amount held as soil mixture. Some of the water that infiltrates through the soil zone is held by capillary forces above the water table; the remainder moves downward by the force of gravity and replenishes the groundwater, causing the water table to rise. Therefore, countrary to popular opinion, each rain does not recharge the groundwater table.

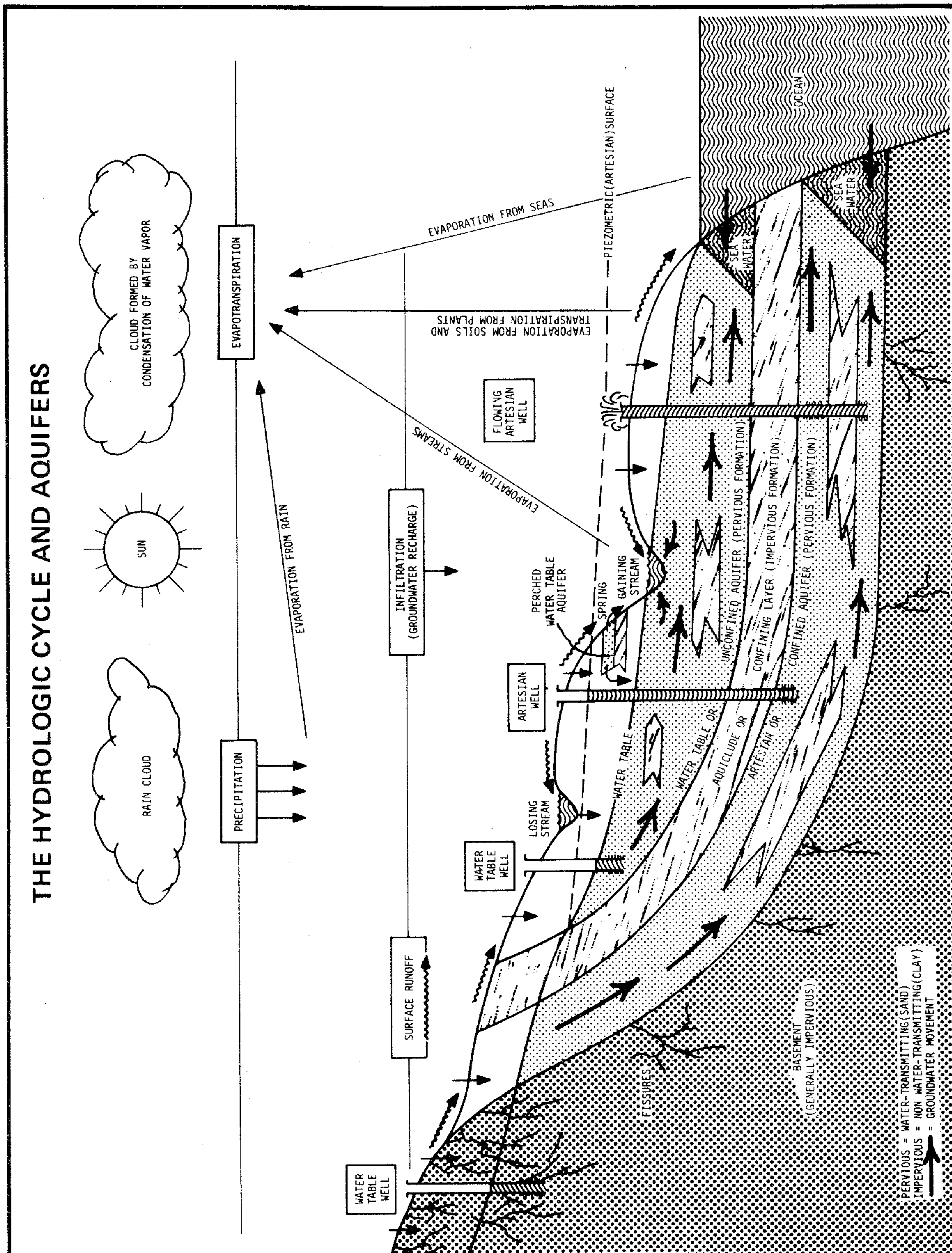
	Ground Level
Zone of aeration	Discontinuous moisture zone Moisture films not connected
(indefinite depth)	
Capillary Fringe Zone	Soil partially saturated, moisture continuous
(indefinite depth)	
Capillary Saturation Zone	Soil saturated, moisture continuous
∇ Water Table	

Figure 2 Soil Moisture Distribution

The surface of the water table is rarely flat, but has undulations usually conforming to the topography. The water table is higher under hills than under valleys. However, the relief of the water table surface is more subdued than the topographic expression. Therefore, the depth to the water table is greater under a hill than under a valley.

The differences in elevation of the water table and the force of gravity cause movement of the groundwater. This movement often results in the natural discharge of groundwater through springs. Springs or seeps occur where the water table intersects the land surface, usually on the sides of slopes and in valleys. Thus, high topographic areas are commonly groundwater recharge zones, and low topographic areas are commonly groundwater discharge zones.

The dominant factor that influences the occurrence of subsurface water is the geology of the area. This is particularly true where



Source: State Water Control Board **PLATE NO. 6**

the underlying solid rocks have a very low permeability. In these cases subsurface fluids are transmitted mainly through fractures and solution openings. The former occur due to deformation forces and the latter due to decomposition of mineral constituents. Such voids are referred to as secondary permeability and are directly related to the structure and lithology of the rock units present (DeKay, 1976).

Groundwater does not flow in "underground streams" except in limestone or dolomite caverns, which are probably limited to the Leesburg area. Instead, groundwater normally flows through the interconnected pore spaces in sediment and fractures in rock. The rate of movement ranges from a few inches per year to a few feet per day.

Groundwater movement in crystalline rock is affected by structures in the bedrock, particularly fractures such as faults and joints. The direction of movement is affected by the alignment and inclination of the fractures. The rate of movement is influenced by the number and size of the fractures, and the depth of movement is determined by the depth to which the fractures extend.

Groundwater movement may be caused artificially by withdrawals at wells. The pumping of a well will cause the water level in the vicinity of the well to drop, resulting in movement of groundwater towards the well. The vertical distance that the water level in the well drops is termed the drawdown. The drained space between the original water level (static water level) and the lowered water level (pumping water level) outside the well is roughly cone shaped, and is termed the cone of depression. The cone of depression spreads outward from the well as it is pumped. The cone of depression eventually will stabilize at some distance for the well if the withdrawal rate is not excessive. If two or more wells are placed too close to each other, the cones of depression of each will intersect and may result in excessive drawdowns, decreased yields, and possibly the "drying-up" of one well.

Aquifers

An aquifer is a geologic formation that is capable of containing and transmitting groundwater. Aquifers may be comprised of unconsolidated sediments or of fractured, consolidated rocks. Groundwater is contained in the pore spaces of sediments, such as sand or gravel, and in fractures or cracks in crystalline rock, such as granite.

Aquifers may be of two types: (1) unconfined or water-table aquifers and (2) confined or artesian aquifers. Both types are present in Loudoun County and examples are illustrated in Plate 6.

In an unconfined aquifer, the water table is the upper surface of the zone of saturation. The surface of the water table is at atmospheric pressure, whereas water below this surface is at a higher pressure due to the weight of the overlying water. In an unconfined aquifer, water is able to infiltrate downward through the zone of aeration and reach the water table.

In an artesian aquifer, the groundwater is separated from the zone of aeartion by a confining layer, such as an impermeable clay bed. Groundwater in a confined aquifer is under pressure in excess of atmospheric pressure. When the confining layer is penetrated by a drill bit, the groundwater quickly rises in the bore hole. The water level in an artesian well stands above the aquifer that the well taps. If the artesian pressure is sufficiently high, the water may flow freely at the surface. However, a well does not have to flow freely for an artesian condition to exist. Cady (1933, 1938) reported there were few to no artesian systems in Loudoun County and what few there were would be limited to the southern part of the basin near the fault line.

The depth to the static water level of an aquifer can be measured in any well that is not being pumped. If the well is in a confined aquifer and the upper water table is cased-off, the measured water level is termed the artesian surface (or potentio-metric surface). In a well tapping an unconfined aquifer in which water from the upper zone is allowed to enter the well, the measured water level is termed the water table. The depth to the groundwater in either case will depend on several factors including: the geologic formation in which the well is drilled, the confining condition of the aquifer, the topographic position of the well site, the time of year the measurement is taken (water levels fluctuate seasonally), and the proximity to pumping wells.

Groundwater sometimes flows for many miles in extended aquifers, but frequently, especially for unconfined aquifers, it has partly or totally originated from surface infiltration within a radius of a few miles of its occurrence. The recharge area for most water-table wells is the immediate area around the well for a radius of several hundred feet. The Triassic Basin tends to act as its own recharge area, with nearly all the absorbed water being used through the wells drilled there or going away as the base flow of the streams. Therefore, it is important what contamination sources are located within the basin. Recharge of an artesian aquifer may occur from lateral migration from the outcrop area of the aquifer or from vertical leakage through semipervious confining beds.

Basement Complex - Blue Ridge Province

The Basement Complex, consisting of the Marshall Formation and other granite-like rocks, is not generally thought of as a good water-bearing complex. Where massive, the rock is practically impermeable except for the faults and joints. Toward the eastern edge of the outcrop area, however, the schistose planes are more open due to tectonics and weathering. Here water for domestic use is generally abundant. The yields decrease below 120 meters (400 feet) as the cracks and joints become sealed by pressure. Cady (1933) reported that below 60 meters (200 feet) a 19 lpm (5 gpm) increase in yield could be expected for every 30 meters (100 feet) of additional depth. Beyond 120 meters he made no predictions.

The controlling factors of many well sites in western Loudoun County are the thickness of the soil overburden, the porosity and permeability of the overburden, the topographic position of the well site, degree of fracturing of bedrock, occurrence of mineralized zones, and the lithology of the parent rock. The first three items affect the storage capacity and rate of recharge of the rock. This is particularly true in the upper zone of the bedrock and in the presence of joints.

The topographic position of the well site is very important, as wells drilled in areas of low elevations statistically have better yields. This is probably due to such areas having buried faults, joint lines, soluable bedrock, and decomposed strata. More to the point, low areas are receiving recharge from higher elevations within the same rock units.

Drilling in the Marshall Formation will, except for local areas, be difficult, accompanied by a high rate of bit wear. Acceptable water frequently will be found just at, or slightly below, the zone of decomposed bedrock. The volume will usually suffice for domestic use. Special screening precautions should be taken when driving the casing in order to take advantage of this water.

Frequently concentrated zones of minerals will produce better water sources than the parent rock. This is true in cases where layers of brittle quartzite are enclosed in granites or basalts; or where calcitic beds are found in between basalt flows or dense conglomerates.

Layered Clastics

This suite of rocks occupies the smallest area, yet contains a great diversity in formations and lithologies. The seven formations include boulder and cobble beds, arkose, phyllite, graywacke, quartz-pebble conglomerate, sandstone, quartzite, limestone, and marble. The possibilities of finding useable quantities of water in the various units are lithologically and tectonically controlled. The lithology effects the water holding and storage capacities chemically, whereas tectoncis caused mechanical breakage.

The Swift Run occurs in outcrop bands and several irregular-shaped areas. Texturally the unit ranges from a boulder bed to medium-grained sandstone.

The banded areas should be considered as poor-quality water-yielding beds, although the irregular bodies in the south central portion of the county have had wells producing in the 25-100 gpm range. The unit probably can be over-pumped easily.

Some of the best-quality water could be expected from the so-called Everona (?) Formation. However, due to the shallowness and erratic occurrence of the marblelike limestones, it cannot be relied upon. Those wishing to exploit the unit should refer to Tinsely Mack's report already mentioned.

As in the case of the Everona (?) Formation, the Loudoun should not be relied upon. Its extremely-limited outcrop and shallowness almost assure that any wells located in it will be of the overburden type or of low output.

The next three formations of the Layered Clastics, the Weverton, Harpers and Erwin, can be lumped together roughly for the discussion purposes. The only unit which has been identified definitely in well cuttings is the Weverton. Indications are, however, that wells have been made in all of the formations. Table 2 presents the water-bearing capabilities of all three. Further discussion of the individual units can be found in Table 5 of Chapter 5.

The last unit of the layered clastics, the Frederick Limestone (Cady, 1938), is limited to a small section north of and adjacent to Route 15, east of Point of Rocks. The thickness of this unit is unknown, as all the confirmed wells in the Frederick are less than 200 feet in depth. The yields have been reported as unknown, but adequate for a family dwelling, up to 10 gpm. It is speculated that this unit should be capable of yields in the 25 gpm-and-above range.

<u>Layered Volcanics</u>

Generally speaking the layered basalt flows, with interbedded metasediments, cannot be considered to be a good source of groundwater supplies. It was noted that prior to the advent of modern drilling technology nearly all the wells in the Catoctin formation were shallow, limited to the overburden. As in many other areas, the topographic position of the well site is of great importance. Low areas, particularly if linear in configuration, could be surface expressions of deep-seated fractures, and fractures serve as better water sources. Such fractures are more numerous nearer the surface and decrease with depth.

The contact surface between wet sediments and volcanic flows or quartz zones are usually good water sources in the Catoctin. However, the chances of predicting such occurrences are found in areas mapped as Marshall Formation. The lines between these units are potentially-better water zones than either formation. Yields from the Catoctin area have almost always been in the poor-to-infrequent-fair range [less than 38 to 76 lpm (10 to 20 gpm)].

Triassic Lowlands

The sedimentary rocks of this large section of the County are the best water sources. Although wells have been drilled to depths of almost 300 meters (1000 feet), and a percentage of wells in the 182-243 meters (600-800 feet) range have been dry or inadequate, it is generally a reliable aquifer. This is due to the geologic controls: i.e., depth, dip, degree of fracturing, lithologies, etc. Nearly the entire basin can be summarized as containing potentially-fair-to-good resources. One area in particular around Leesburg is evaluated as very good, 378.5 to 946 lpm (100-250 gpm) wells being common.

One groundwater danger which exists in the Triassic, particularly around Leesburg, however, is the practice of overpumping. This act, committed in order to obtain, rapid, high volumes of water, can lead to a loss of hydraulic lift for the overlying rocks and soils above the water body. Such a loss ultimately will lead to compression of the aquifer, or units above it, and subsidence of the surface. Often this can be severe enough to cause an actual hole to open to the surface. Such a hole poses a threat to structures and human life as well, as being an entry point for contaminants into the water table. Such events already are occurring in the Triassic deposits.

Further information concerning the wells in the Triassic can be found in Table 6 and Appendices A and B.

CHAPTER IV

GROUNDWATER QUALITY

The use of groundwater for human consumption or industrial use is affected directly by its quality. This quality is determined by naturally-occurring circumstances, but can be altered, both to the good and bad, by man's activities.

Constituents in Natural Groundwater

As water falls through the atmosphere and percolates through soil and rock material, gases and mineral matter become dissolved and/or suspended in the water. The solids and gases contained in water influence its chemical and physical properties, such as hardness, acidity/alkalinity, corrosiveness, taste, color, odor, etc. Some of the dissolved constituents, such as fluoride (if not excessive), are beneficial; others, such as iron are troublesome. Consultation with the Virginia Department of Health is needed for determining groundwater potability.

The most common constituents of natural groundwater include calcium, magnesium, sodium, bicarbonate, sulfate, and chloride ions. Other constituents commonly present, but usually in lesser amounts, include iron, manganese, silica, potassium, fluoride and nitrate ions. Table 4 lists other constituents and their allowable parts-per-million established by the Virginia Department of Health and the State Water Control Board.

Calcium (Ca) and Magnesium (Mg) These two elements, in the form of cations (positively charged ions) are responsible for most of the hardness and scale-forming properties of water. Water containing

TABLE 4

VIRGINIA GROUNDWATER STANDARDS
(for human consumption)

Table 4.1 Inorganic Chemicals

Substance	Primary Maximum Contaminant Levels (mg/l)
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.010
Chromium (Cr)	0.05
Fluoride (F)	1.8 #
Lead (Pb)	0.05
Mercury (Hg)	0.002
Nitrate (as N)	10.0
Selenium (Se)	0.01
Silver (Ag)	0.05
Cyanide (CN^-)	5.0

Substance	Secondary Maximum Contaminant Levels (mg/l)
Chloride (Cl)	250.0
Copper (Cu)	1.0
Foaming Agents	0.5
Hydrogen Sulfide	0.05
Iron (Fe)	0.3
Manganese (Mn)	0.05
Sodium (Na)	No Limits Designated, See Text
Sulfate (SO_4)	250.0
Zinc (Zn)	5.0
Total Organic Carbon	10.0

Note. For artificially fluoridated waterworks the minimum concentration of fluoride should be 0.8 mg/l and the maximum should be 1.0 mg/l. The optimum control limit is 0.9 mg/l.

TABLE 4 cont.

Table 4.2 Organic Chemical

Substance	Primary Maximum Contaminant Levels (mg/l)
Chlorinated Hydrocarbon Insecticides	
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
Aldrin/Dieldrin	0.003
Chlrodane	0.01
DDT	0.001
Heptachlor	0.001
Kepone	none
Mirex	none
Chlorophenoxy Herbicides	
2, 4-Dichlorophenoxyacetic Acid (2, 4-D)	0.1
2, 4, 5-Trichlorophenoxypropionic Acid (2, 4, 5-TP or Silvex)	0.01
Petroleum Hydrocarbons	1.0
Phenols	0.001

Table 4.3 Physical Quality

Parameter	Concentration
Color	15 Color Units
Odor	3 Threshold
pH	6.5-8.5
Total Dissolved Solids (TDS)	500 mg/l
Turbidity	1 Turbidity
Alkalinity	10-200

less than 75 milligrams per liter (mg/l) (correlative with parts per million) is thought to be soft and above 75 as hard (Gass, 1978). A great body of literature suggests that there is a relationship between the hardness of water and the incidence of cardiovascular disease. That is, that the softer the water the higher the occurrence. It is indicated that high-hardness waters tend to be low in various harmful constituents: i.e., cadmium, lead, copper, and zinc, which may cause other diseases. All the facts are not complete in either of the two theories, (Gass, 1978). It is known, however, that a high concentration of magnesium can have a laxative effect on the user. High concentrations of calcium, on the other hand, have not been found to be at all harmful.

Sodium (Na) and Potassium (K) In high parts per million these cations can give water a salty taste in combination with chloride. If a person is on a low-sodium diet for hypertension, the water should contain less than 20 mg/l. A sodium-restricted diet should contain less than 2000 mg/day. Normally groundwater is far less than this, rarely exceeding 250 mg/l. It is estimated, however, that up to 40% of all Americans would benefit from a reduced sodium intake; but the quantity derived from water is small.

Iron (Fe) and Manganese (Mn) These constituents cause stains on laundry, cooking utensils, and porcelain fixtures. They also contribute to hardness and may impart an objectionable taste and color to food and beverages.

Bicarbonate (HCO_3) Bicarbonate ions are responsible for most of the alkalinity in water and combine with calcium and magnesium to form boiler scales.

Sulfate (SO_4) Sulfate combines with calcium to form boiler scales and may impart a bitter taste to water when present in excess of 500 mg/l. Water containing 1000 mg/l may be strongly laxative in effect.

Chloride (Cl) In excess of 100 mg/l, chloride imparts a salty taste.

Fluoride (F) Concentrations of fluoride of approximately 1 mg/l, depending on temperature, are generally thought to be beneficial by reducing the occurrence of cavities in teeth. Several harmful effects have been attributed to high fluoride water, such as skeletal fluorosis (bone densification), mottling of tooth enamel, mongolism, cancer and birth defects. No evidence of any of these problems, except the first two, is supportive.

Nitrate (NO_3) All sources of combined nitrogen represent a potential source of nitrate. There are two health hazards related to the consumption of water high in nitrates. These are the possibilities of methoglobinemia in infants (blue babies) and the possibility of the formation in the body of nitrosomines, which may be carcinogenic (Gass, 1978). Studies have shown that infants are suspectible to as low concentrations of nitrates as 10 mg/l.

Specific Conductivity A measure of the ability of water to conduct an electric current. Specific conductivity is an indicator of the relative amount of dissolved minerals in water.

Hardness Other than the discussion of hardness under the Calcium and Magnesium section, it should also be mentioned that hardness causes excessive use of soap. By Virginia standards water with a hardness less than 60 mg/l is considered soft; 60-120 mg/l, moderately hard;

121 to 180 mg/1, hard; and greater than 180 mg/1, very hard.

pH A measure of the hydrogen ion concentration, pH indicates whether water will act as a weak acid or an alkaline solution. The pH scale ranges from 0 to 14 with 7.0 being neutral; greater than 7.0 indicating an alkaline solution, and less than 7.0 an acidic solution. Corrosiveness of water generally increases with a decreasing pH, although highly alkaline water may be corrosive. Corrosive water may attack steel casings or copper plumbing.

As essential nutritive substances, both major and minor (trace) elements are often found in well water. Twenty-five elements are supposedly essential to life (Keller, 1978). At least 14 of the 25 are essential for humans as trace elements. These are Fluorine (F), Silicon (Si), Vanadium (V), Chromium (Cr), Managanese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Selenium (Se), Molybdenum (Mo), Tin (Sn), and Iodine (I). These elements, though needed, easily can be too concentrated and then become toxic to humans. The known allowable concentrations of the various elements are presented below where not discussed previously:

Silicon Other than being bound up chemically in soil and rock, thus causing cloudiness, it is not known to be harmful in drinking water.

Vanadium Commonly found in many soils, vanadium appears to be useful in preventing and breaking up excess cholesterol in humans. Excess quantities, however, in combination with other elements, can be dangerous. Apparently concentrations of 0.03 to 0.22 mg/1 are safe (McKee and Wolf, 1963).

Copper Metallic copper is unsoluble in water; however there exists many copper salts. Under special conditions the concentration can go as high as 21 mg/l. Dangerous concentrations of copper for human consumption generally are impossible to consume, as the taste becomes very disagreeable. In the body, trace quantities aid in nutrition and the metabolism of iron in the blood. The daily intake of copper is generally 2-5 mg/day. There is no evidence that poisoning has ever occurred as a result of consumption of copper in water (McKee and Wolf, 1963).

Zinc The normal human intake is 10-15 mg/day and is useful in nutrition. High concentrations (variable) are blamed for nausea and fainting in reported cases of occurrence in groundwater. Normally zinc will either be noticed as a greasy coating or by taste before it becomes dangerous.

Selenium Proof of human injury by selenium is scanty, and definite symptoms of selenium poisoning have not been proven; but it is widely believed that selenium is highly toxic to man (McKee and Wolf, 1963). Yet it is essential for nutrition, and recent findings by Dr. Joel D. Wallach, in Chicago, have indicated that a selenium deficiency during pregnancy can cause cystic fibrosis. The poisoning effects are similar to that of arsenic, with the material retained in the liver and kidney. The element also seems to cause a high incidence of cavities in permanent teeth.

Molybdenum The Environmental Protection Agency reports that it is not considered to be a serious pollutant, but it is a biologically active metal. It does serve an important function in the life processes of phytoplankton (Arnon and Wessel, 1953) but excessive exposure in mammals may interfere with vital, internal, chemical reactions (Dick and Ball, 1945).

Tin Does not occur naturally in groundwaters. Therefore its presence in a well would be indicative of contamination.

Iodine This element helps assure proper functioning of the thyroid gland and the subsequent reduction of goiter. There are recorded cases of human consumption of iodine-rich water at concentrations as high as 19.2 mg/day.

Water Quality in Loudoun County

Groundwater quality in Loudoun County is variable, but not surprisingly so when one considers the varied rock types encountered in the county. As a general rule water from acidic (granite-like) rocks is "soft" chemically; although it can be corrosive and sometimes iron-bearing. Other high-level, quartz rocks, i.e., sandstones and quartzites, can have similar traits. On the other hand, the basic rocks, basalts, gabbros and such, tend to be high in ferro-magnesian minerals, that is iron and magnesium. Groundwater from the Triassic Basin is generally hard to very hard, very high in dissolved minerals, and tends to be alkaline.

The reader must keep in mind that wells sampled by the State Water Control Board for groundwater quality data vary in age and state of repair. Naturally, older wells, or those recent ones not built to modern standards, are susceptable to contamination from outside sources. These sources can include septic tank drainfields, faulty underground storage tanks and animal lots. This possibility for local contamination may be one of the reasons to account for differences in water quality within the same rock type.

Several lists showing water quality in the county are included in this report. Table 5 lists the maximum and minimum concentrations and the values for the constituents in the groundwater of the various aquifers in the county, based on chemical analysis available for this report. Appendix B is a summary of water quality analyses of samples taken from individual wells throughout the County. The hardness trends of the groundwater are illustrated in Plate 7 based on the data from Appendix B.

Triassic Lowlands Plate 7 shows the distribution of water hardness in the Triassic Basin. Although a few wells in the western part of this area yield "hard" water, the bulk, of the water is "very hard" as we would expect from the geology. Levels for dissolved solids are high, but in no cases excessive. Also much of the area contains alkaline groundwater, but only slightly so.

Sulphate levels are lower in this area than other parts of the county, and sodium levels are higher. This is, perhaps, due to the sedimentary history of the Basin. Nitrate levels appear to be significantly high in this area, but the reader is cautioned to consider the narrowness of the statistical base and the possibility of local contamination before postulating any theories for this condition. Additionally, it must be remembered that this average is well within acceptable tolerances.

Layered Clastics These rocks also conform to geologic expectations. Water from these formations tends to be slightly acidic. Although the samples exhibited all degrees of hardness, it would appear that, for the most part, water in these rocks is only moderately hard. Levels for total dissolved solids in the layered clastic rock area tend to be lower than levels in other areas.

Table 5 indicates that iron levels are higher than in other areas. This may be attributed to the lower pH. Bicarbonate levels are lower in the water in this region, whereas nitrates, chloride, sodium and potassium are consistent with those of the rest of the county.

Layered Volcanics Unfortunately, very few of the wells sampled for groundwater quality were in areas underlain by these formations. For this reason, drawing conclusions from the data presented is a risky proposition.

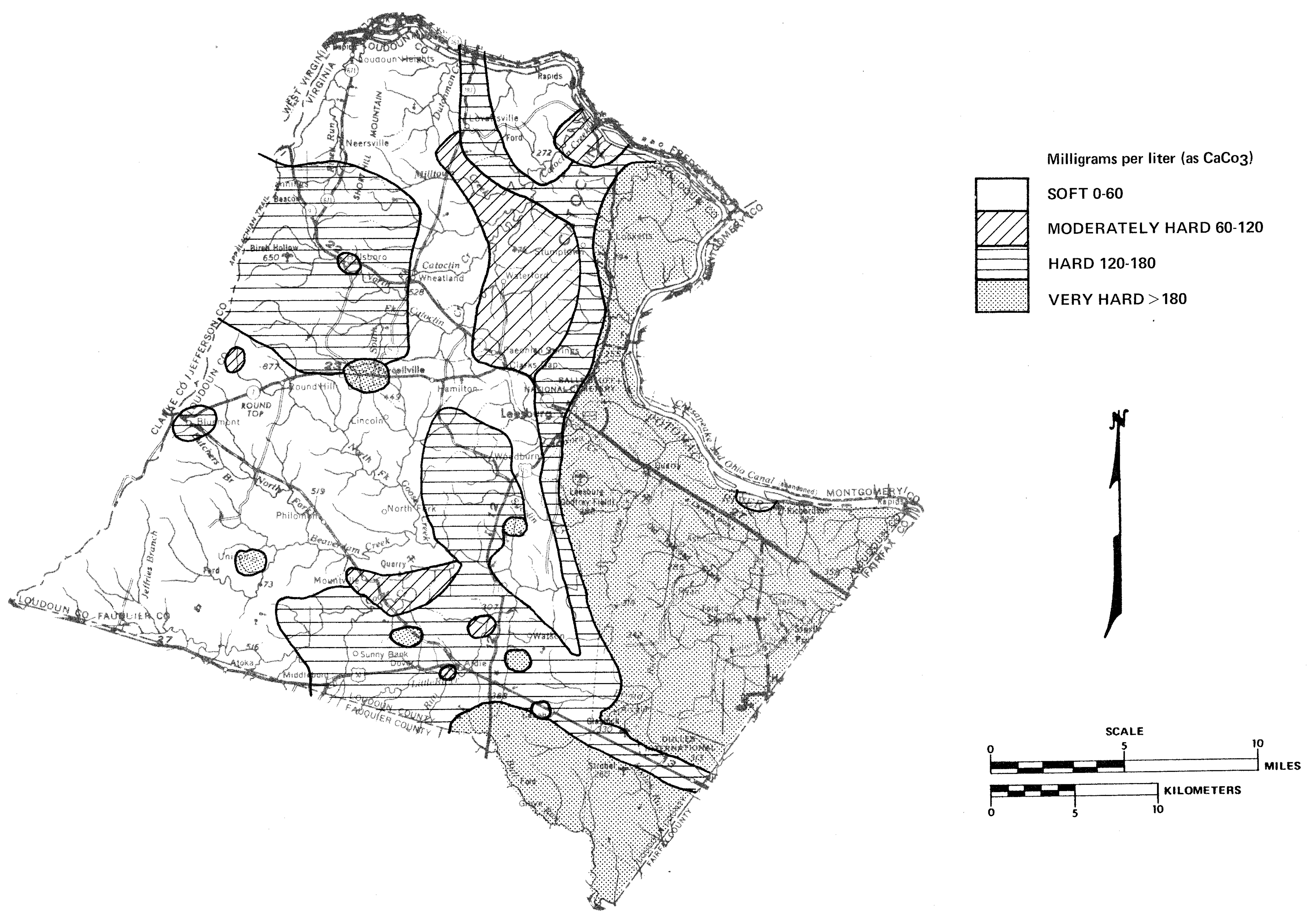
The data tentatively show that these formations produce water that is slightly acidic. This water appears to be slightly harder than that of the layered clastics, but still tends to be only moderately hard.

Averages for sulphate may tend to be higher, whereas averages for chlorides may tend to be lower than the averages for these compounds in the rest of the county. Nitrate, potassium, sodium, and iron levels appear to be about the same as in those other areas.

Basement Complex These rocks yield water that is slightly alkaline. This is surprising, since we would expect the water from granitic rocks like these to be acidic. It could be that the wells sampled were in close conjunction to mafic intrusions. This relationship would skew the data toward the basic side. Most samples fall into the hard or moderately-hard categories.

Levels for total dissolved solids are in keeping with those in

TRENDS OF GROUNDWATER HARDNESS IN LOUDOUN COUNTY



Source: Virginia State Water Control Board — NRO

PLATE NO. 7

the rest of the county and are not intolerable. Sulphate, carbonate and chloride levels are high in comparison to the other groups of formations discussed in this report. Nitrate levels are acceptable, with occasional high levels. These high levels may represent localized contamination.

Groundwater Contamination

Groundwater Contamination refers to the introduction of an organic or inorganic material, foreign to the native groundwater, that tends to limit the useability of the groundwater. If contaminants are added to the groundwater to the extent that it becomes nonpotable or unusable, the groundwater is said to be polluted. Groundwater pollution usually is more serious than surface water pollution, since reversal is very difficult and costly. The self-cleansing mechanisms available to streams, i.e., fresh-water flushing and oxygenation, operate very slowly in groundwater, if at all.

Sources of groundwater pollution are many and varied. Miller and Scalf (1974) presented a synopsis of the subject in a nationwide investigation sponsored by the U. S. Environmental Protection Agency. In Loudoun County, the more significant sources of groundwater pollution include: septic-tank systems, sanitary landfills, sewage lagoons, petroleum spills, leaking pipelines, leaking gasoline storage tanks, improperly-constructed water wells, certain agricultural activities (fertilizers, pesticides, feedlot and barnyard wastes), highway deicing salts and infiltration of poor quality surface water from lakes and streams.

Septic tank drainfields, by sheer volume of waste water discharged, have the greatest potential for contaminating groundwater.

A drainfield is considered failing if the sewage backs up in the house or floods the land surface. A properly operating drainfield acts as a source for groundwater recharge. Miller and Scalf (1974) state that "Studies have shown that in many housing developments recycling of liquid wastes is an inevitable fact of life."

Septic-tank systems commonly are believed to purify sewage. Actually, the degree of treatment that waste water receives in a septic system is rarely high. In suitable soils, most bacteria are effectively removed by filtration and biological degradation. However, many soils have a low capacity for the purification of waste. Some soil profiles are too thin to assimilate all of the wastes. Moreover, not all of the undesirable constituents of domestic sewage are completely biodegradable. Considering the seriousness of an improper drainfield, and its potential for causing groundwater pollution, land always should be checked by a soil scientist or Health Department official prior to the installation of a drainfield. Miller et al (1974) states, "Under normal conditions of soil pH, efficient removal of phosphates can take place, but chlorides, nitrates, sulfates, and bicarbonates can enter and move freely within a groundwater body."

Nitrates are the most significant constituents (other than bacteria or viruses) of domestic sewage entering groundwater and lowering its quality. In Loudoun County, the nitrate content of natural groundwater is generally low. High concentrations of nitrate most likely indicate contamination. The most likely sources are septic tank effluent and nitrogen fertilizers. In areas where infiltration of nitrogen fertilizers is insignificant, the nitrate content is a good tracer for septic tank contamination. The Triassic lowlands are probably the most vulnerable area to nitrate contamination in Loudoun County. The soils are relatively thin, and their capability for assimilating and filtering wastes is limited. The shale and sandstone bedrock is highly fractured. The fractures are inclined 15^0 to 20^0 from the horizontal, providing a natural conduit to the water table for liquid contaminants, with little opportunity for filtration and quality improvement. The age of a septic system is a significant factor in groundwater quality, since continuous nitrogen loading causes a build-up of nitrate over a period of years. Lot size and housing density are also very important.

Pollution of groundwater by petroleum hydrocarbons is a very serious, common, and unfortunately, growing problem. Most instances are confined to local areas and involve only one or a few potable water wells. However, there have been cases of large-scale groundwater pollution from petroleum, (McKee et al, 1972 and Howard, 1978). In Loudoun County, minor cases have occurred, but, as yet, no major ones. The principal causes of hydrocarbon contamination include: leakage from storage tanks, leakage from buried pipelines, spills or leaks at bulk storage areas, and transportation spills. Many types of petroleum products are involved, but gasoline and heating oil are the most common. Slow leaks can go unnoticed at a service station until wells become polluted, neighbors smell hydrocarbon fumes in their houses, or customers get water in the gasoline they purchase. In very serious cases, such as the village of Port Loring in Ontario, Canada (Howard, 1978) the water coming from household taps can actually ignite.

The clean-up of subsurface petroleum pooling is difficult, costly, and often ineffective. Alternate water supplies often have to be found when a well is contaminated. A publication which offers solutions to problems involving hydrocarbon contamination of groundwater has been prepared by the American Petroleum Institute (1972).

The human threshold for the detection of gasoline can be as low as 0.005 mg/l, so a small amount of gasoline can render a water well unusable. Recent studies have shown that certain bacteria will degrade gasoline in the groundwater environment, if adequate nutrients and dissolved oxygen are available. However, there are cases in which gasoline has remained in soil for more than 70 years (McKee et al, 1972).

It is beyond the scope of this report to provide a detailed discussion of all the causes and effects of groundwater pollution. Groundwater conditions are so variable and potential contaminants are so numerous that most cases are unique. Any known or suspected case should be reported to the appropriate County or State health officials and/or to the State Water Control Board.

TABLE 5

SUMMARY OF ANALYSES OF GROUNDWATER
(expressed as mg/l)

	pH	Spec* Cond	TDS	Hard ness	Fe	Ca	Mg	Na	K	HCO_3	SO_4	Cl	F	NO_3	Aquifer
Minimum	6.2	112	17	52.2	0.01	1.2	0.6	0.6	0.1	11	0.0	1.6	0.0	0.01	Triassic Lowlands
Maximum	8.0	1300	364	636.3	1.1	636.3	54.5	46.0	15.8	224	20.0	46.0	0.32	92.1	
Average	7.1	402	175	200.0	0.14	55.5	17.4	15.2	1.5	151	4.3	14.0	0.13	5.6	
Minimum	5.5	27	46	15	0.01	4	1.2	1.0	0.1	12	8.2	1.0	0.10	0.05	Layered Clastics
Maximum	7.4	568	90	298	9.8	70	30.0	50.0	4.2	45	15.0	41.0	0.10	14.4	
Average	6.6	218	68	98	1.1	24	8.9	10.9	1.8	29	12.4	12.1	0.10	2.6	
Minimum	6.2	95	165	33.6	0.1	9.0	2.7	5.0	6.9	---	12.8	0.1	0.13	1.3	Layered Volcanics
Maximum	7.3	440	234	218.2	0.3	61.0	18.3	10.4	0.8	---	36.5	9.0	0.17	9.0	
Average	6.8	243	200	122.1	0.1	30.2	11.4	8.1	2.7	---	24.7	5.5	0.15	3.8	
Minimum	6.0	54	42	21	0.00	4.8	0.2	1.8	1.0	118	0.9	1.0	0.0	0.0	Basement Complex
Maximum	8.1	462	360	332	3.20	96.0	32.0	50.0	11.0	188	43.9	107.0	0.3	25.0	
Average	7.2	233	184	121	0.56	32.0	9.5	12.6	4.1	136	14.7	14.7	0.19	3.1	

* Specific Conductivity

CHAPTER V

GROUNDWATER DEVELOPMENT

General Setting

Groundwater is developed widely in Loudoun County in domestic and public water systems. Water wells in the County are of three types: drilled, bored and hand-dug. Most drilled wells are now constructed by rotary drilling machines. Bored wells are constructed by large diameter, (610 to 1220 millimeters (24-48 inches)), boring machines or earth augers. Hand-dug wells, once common in the Piedmont, now are rarely used for potable water supplies.

Drilled wells are usually 101.6 to 457.2 millimeters (4-18 inches) in diameter; the most common size now favored is 152.4 millimeters (6 inches). Steel casing is installed from the surface through the weathered zone and seated into the bedrock. The zone between the outside of the casing and the well bore (annular space) is grouted with cement from some predetermined depth to the surface. This cement grout is to prevent surface contaminants from seeping down the well bore.

Bored wells are common in the Piedmont and Blue Ridge Provinces. In all cases, they are terminated in the weathered zone, since boring machines cannot penetrate hard rock. Bored wells are lined with concrete pipe instead of steel casing. Water enters a bored well at the bottom, which is open. Bored wells are not usually grouted except at the surface, and therefore, are more susceptible to contamination than properly-constructed drilled wells. Bored and hand-dug wells also are more vulnerable to drying up in times of prolonged drought, since their depths are limited.

Public Supplies

The construction of public water-supply wells is regulated by the Virginia Department of Health (1974). A well is designated a public supply if it serves 15 connections or 25 people. Public water-wells are required to be cased and grouted to a depth of at least 50 feet (sometimes greater depths are required) and to provide a supply of at least 1.9 lpm (0.5 gpm) per connection.

Public water-supply wells are relatively numerous in Loudoun County. The highest concentrations are in the Leesburg and Hamilton area. The Leesburg wells, of greatest productivity, are located in the Triassic-age limestone conglomerates and diversified units of the Bull Run Formation to the South. The Hamilton wells, on the other hand, are located in the Marshall granite-gneiss and nearby contact zone with the Swift Run formation. By State Water Control Board records, the Town of Leesburg has, or still owns, twenty-five (25) wells. Most of these have been abandoned or capped-off due to becoming dry, or because of inadequate water quantity when they were drilled. Hamilton is credited with owning, or having drilled, sixteen (16) wells, some for subdivisions. At least six (6) of these have been abandoned. Foxcroft School near Leithtown has had seven (7) wells, four (4) of which are operational at present, though rapidly declining. The drillers logs for this area exhibit a very confusing assembly, but it appears that some wells are in granite-like material and some in the Swift Run. There are indications of a fault structure near Foxcroft School as well. Other known, public-well systems are at Lovettsville, Middleburg, and Hillsboro. Round Hill is contemplating a well-reservoir system.

In addition to these mentioned systems, some subdivisions, notably Moorcones, Potomac Farms, Andover Meadows, and Richland Acres, own their own well(s). Several churches, schools, and light industries are also listed as owning wells. No heavy industry is known to be using wells in Loudoun County.

Considering all the wells recorded in the name of Leesburg, 1.73 mgd output is calculated. The output of other well systems in the County are computed as follows: Hamilton - 0.4 mgd; Middleburg - 0.2 mgd; Lovettsville - 0.35 mgd; and Foxcroft School - 0.13 mgd.

Key Water Wells

Appendix A lists those wells in Loudoun County for which adequate records exist to allow inclusion in the state monitoring-sampling program. The State Water Control Board number is repeated in Appendix B, where applicable. It is immediately noticeable that only 80 wells have been monitored, only 115 are displayed on Plate 8 and only 375 wells are shown in Appendix B. Yet the U.S. Census Bureau estimates that there about 5000 wells in Loudoun County. Unfortunately many wells were constructed prior to the implementation of the Groundwater Act of 1973, discussed later, and to date have not been found. Even when found, a large percentage of owners know nothing about their wells. Also, unfortunately, many modern well owners are not aware of their responsibilities to report, or require the drillers to report, their wells.

Therefore, the availability map and discussions of present and potential water resources are based on a limited statistical base and informed scientific conjecture. Persons using this document are urged to contact the local office of the State Water Control Board to supply further information about any incompletely-reported wells in Appendix B, or to report the existence of wells not shown. In addition, if a user notices a well in Appendix B which is known to be abandoned, the Board would like to know about it in order to keep its records updated.

The Groundwater Act of 1973

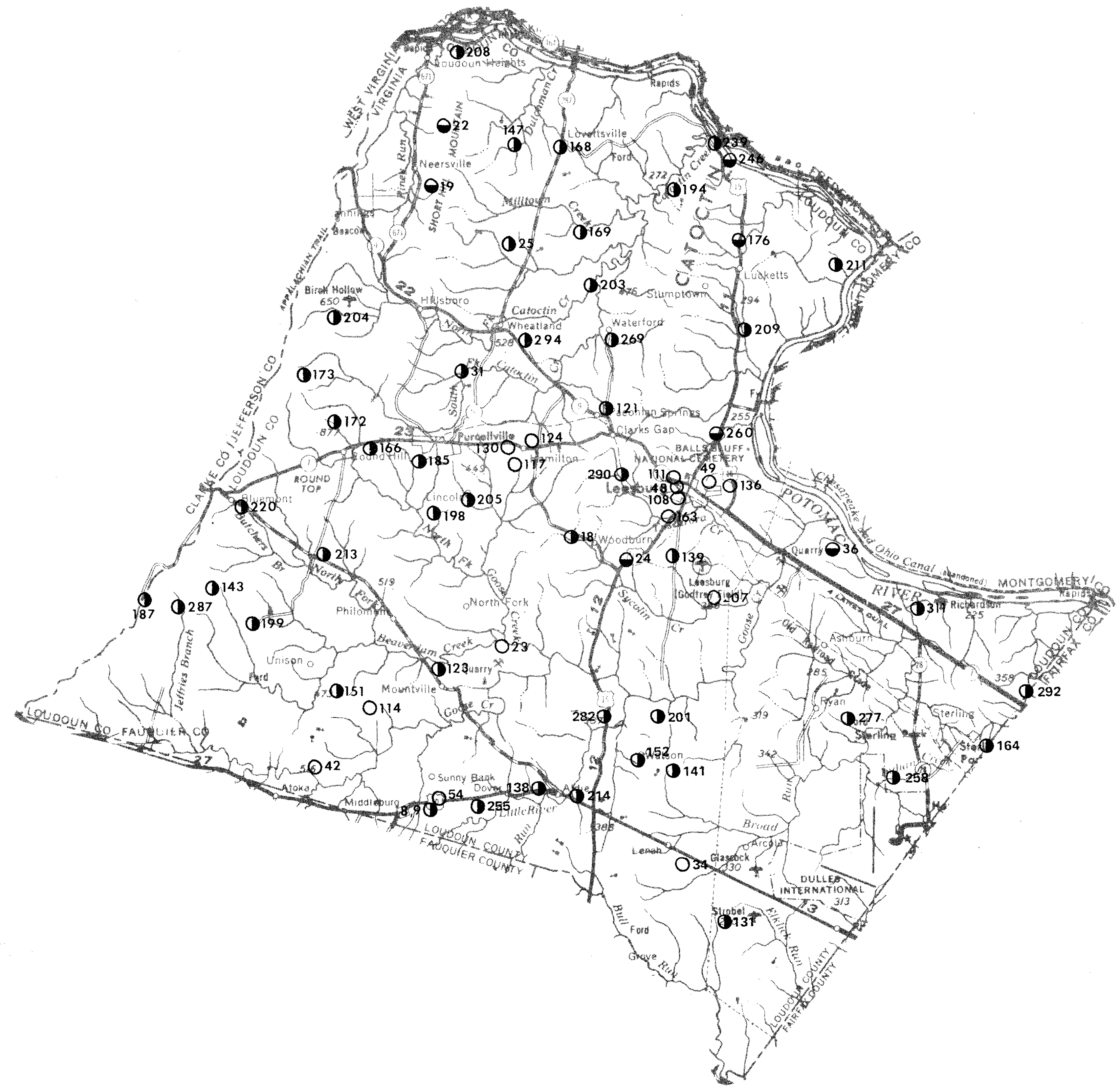
The General Assembly of Virginia passed the Groundwater Act of 1973 (Chapter 3.4, Title 62.1, Code of Virginia, 1950, as amended) "...in order to conserve, protect and beneficially utilize the groundwater of this State and to ensure the preservation of the public welfare, safety and health....Concern for adequate groundwater supplies in the future and protection of groundwater quality prompted this legislation."

The Groundwater Act provides for the declaration of a Ground Water Management Area (GWMA) in a geographically-defined region which experiences, or can be expected to experience, problems with interference of wells, water level declines, overdraft of groundwater, or quality of groundwater.

Requests of a declaration of a GWMA can be made by local government, the State Water Control Board, or the public at large. In either case, a detailed study of the proposed GWMA would be made, and public hearings would be convened to determine the necessity and desirability of designating an area a GWMA.

Industrial and commercial groundwater users in a GWMA who withdraw more than 50,000 gpd are required to file a Registration Statement (Form GW-4) with the State Water Control Board. Prior to

KEY WATER WELLS IN LOUDOUN COUNTY



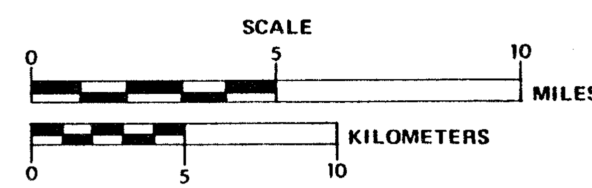
LEGEND
TYPE OF WELL

○ PUBLIC

◑ DOMESTIC

◒ COMMERCIAL

49 WELL NUMBER KEYED TO APPENDICES A & B



Source: Virginia State Water Control Board – NRO

the construction of a new well in a GWMA, the owner is required to submit an application and a Permit to Construct a Water Well and to Use Groundwater (Form GW-3).

In all groundwater areas, users are required to submit a Water Well Completion Report (Form GW-2) for new wells. All public and industrial users are required to submit a Groundwater Pumpage and Use Report (Form GW-6) to the Board quarterly. When an industrial or public well is to be abandoned, the owner must submit an Application and Report - Abandonment of Water Well (Form GW-5).

Further explanations are included in the Guide for Water Well Contractors and Groundwater Users and in the Rules of the Board and Standards for Water Wells, both publications by the Virginia State Water Control Board (1974).

Groundwater Availability

The availability of groundwater in areas of the County is illustrated on Plate 9. This map is based on existing well records, the occurrence of the geologic formations, and their general water-bearing characteristics. Additionally, local areas which are known to be particularly good, bad or suspect are designated.

The map on Plate 9 is general in nature and all unique areas of either high or low productivity cannot be shown. This is particularly true along the major fault systems and in the broad Marshall Formation to the west and the central Triassic Basin to the east. Normally wells in the Marshall zone are poor to fair in yield; although anomalies have been observed in the vicinities of Purcellville, Hamilton, and Wheatland which yielded water in the "good" range. Another high-yield anomaly was noted in the area about one mile south of Sunny Bank. One other high-yield anomaly was in the area of the headwaters of Dutchmans Creek, two miles west of Lovettsville. All these above-normal regional yields were in the 95-378 lpm (25-100 gpm) range.

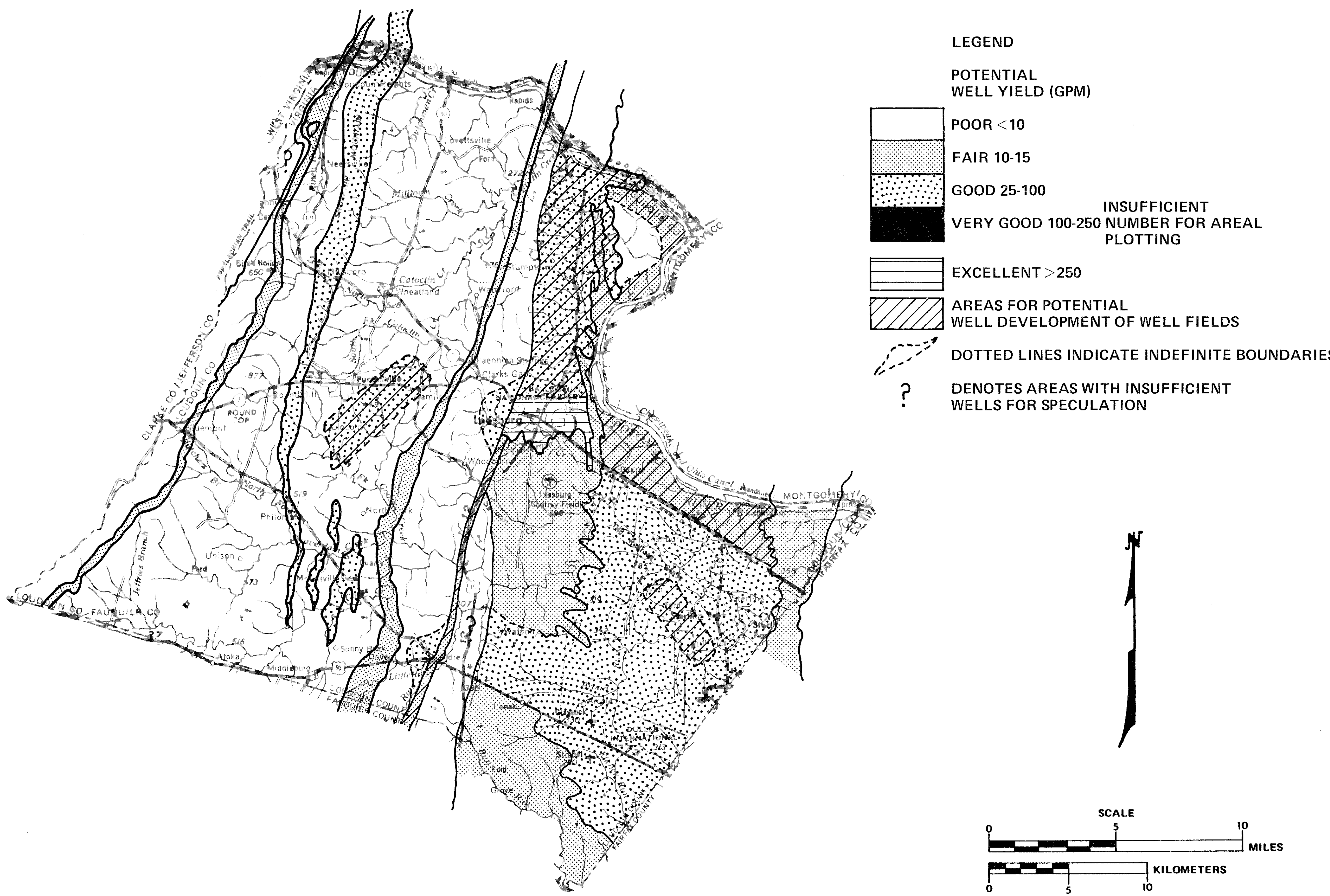
The easternmost Catoctin belt also has two zones of unexpected yield, as shown on the map. These areas lie just west of Aldie and Leesburg. The exact boundaries of these "lobes" are unknown; therefore the configuration shown on the map is speculative.

In addition to the above, there exists the hint of high-yield anomaly all along the Swift Run-Catoctin Contact. It is on this contact that the unidentified, but previously-called "Everona limestone" is found. The width of this outcrop belt is too small to be shown on the plate.

Continuing eastward, the entire Bull Run Fault zone is a potentially-high, groundwater-yielding area and deserves far more investigation and exploitation. The geologic characteristics, i.e., fault dips, fracturing, bedding dips, and proximity to the Potomac River all indicate good groundwater conditions.

Another large area which should receive more attention is bounded by the section of the fault north of Leesburg and Route 7. This area, shown covered with obliquely dipping lines on Plate 9, contains three (3) presently-known groundwater zones. The northern leg of the region, in particular, being Triassic-limestone boulder conglomerate, should be locally highly productive. The shaded area bordering the Potomac River could also be highly productive. This productivity would be due not only to the geology, Manassas Sandstone and Balls Bluff Siltstone, but due to the possibilities of infiltration of water from the Potomac. Public information assistance is requested for all wells in

GROUNDWATER AVAILABILITY IN LOUDOUN COUNTY



Source: Virginia State Water Control Board — NRO

PLATE NO. 9

this area.

The largest, single water zone in the eastern half of Loudoun is rated "good", with one undefined area containing some wells rated "very good." This smaller area does not, however, contain enough wells to be accurately defined. It should also be realized that there are local areas within the large area that are completely devoid of water. Property owners with small lots should keep this in mind when planning water systems.

Reviewing the data presented on Plate 9, it should be noted that two (2) areas of the map are left blank and marked with a question mark. The first zone is a very narrow slice along the western border marked as €w on the geology map. Physically this area is bounded by the base of the Blue Ridge and the County line and runs south, narrowing to just south of Purcell Knob. The State Water Control Board has no recorded well in this area. Therefore, no speculations other than theory can be made. Based on theory there should be potential for some fair wells in this zone.

The second area is found between the Bull Run fault line and the first basalt flow (most eastern), as defined by K. Y. Lee (1977). The geology in this area is very complex, containing highly-variable, clastic rock units interrupted, or locally covered, by hydrothermally altered basalt flows. At present there exists an inadequate number of wells in this area on which to base any conclusions. The few wells reported have been poor to fair in yield.

As a general statement, it could be said that the water resources are at present greater in the Triassic Basin section of Loudoun County, than anywhere else. If investigated, the Bull Run Fault zone may exceed the water yields of the Triassic Basin on a local level. Even in a case where a well does not meet a homeowners expectations, there are actions which can be taken in order to assure a dependable water supply. The extracted article from the Water Well Journal of November 1978 (Appendix C) explains three possibilities.

Well Depths

Considering both the old data reported by Cady (1938) and the modern data assembled by the State Water Control Board, the average productive ranges of wells found in the various geologic units in Loudoun County are given in Table 5. The older wells tend to be much shallower than those drilled with present technology. Also only reported productive wells were used in computing the figures presented. Doubtless there are wells in all the geologic areas which exceed the parameters but have never been reported. It will remain the task of the future to upgrade the data when the base improves.

The data for the Loudoun and Everona Formations were adjusted to compensate for the increasingly-popular and necessary practice of "subdrilling". This is a process of drilling, often as much as 300 feet, below the water-bearing horizon. This provides a storage capacity of 18.2 lpm (1.5 gallons per foot).

It should also be mentioned that the depth of the deepest well shown for the granite unit is highly suspect. One would not expect to find water in granite below 400 feet. In fact, LeGrand in a 1954 report of 520 wells in crystalline rocks showed that the average yields per foot decreased rapidly below 60 meters (200 feet). This appears to be true in Loudoun County as well.

Another item to remember in using the depth vs. geologic unit guidelines is that in the thinner formations, i.e., Loudoun, Everona (?), Swift Run, Weverton, Harpers, and basaltic flows, a well may penetrate to the underlying unit. In some cases such an event is instantly recognized, but in other instances a driller may not notice the transition.

TABLE 6

WELL DEPTH SUMMARY

Geologic Unit	Depth Range	Average Depth	90% Probability Range
Marshall & all other granite-like rocks	4.5-304m (15-999 ft)	56m (184 ft)	10.7-152.4m (35-500 ft)
Catoctin formation	4.5-215m (15-704 ft)	37.5 (123 ft)*	9.5-102m (31-335 ft)
Loudoun formation+	12.8-61m (42-200 ft)	26.8 (88 ft)	15.2-58.5m (50-192 ft)
Everona formation+	7.6-36.6m (25-120 ft)	18.6 (61 ft)	9-35m (30-115 ft)
Swift Run formation	16.1-186m (53-610 ft)	70.1m (230 ft)	21.3-152.4m (70-500 ft)
Weverton formation	12.2-157.3m (40-516 ft)	33.5m (110 ft)*	19.5-150m (64-491 ft)
Harpers formation	50-164.6m (165-540 ft)	86.9m (285 ft)	56.4-158.5m (185-520 ft)
Frederick Limestone+	11-56.1m (36-184 ft)	insufficient data base	
Newark Gp-Leesburg Limestone	8.5-221m (28-725 ft)	54m (177 ft)	10-152.4m (33-500 ft)
Manassas Sandstone	15.2-91.4m (50-300 ft)	37.5m (123 ft)	15.9-62.5m (52-205 ft)
Basalt-flow/bearing Clastics member	18.9-103.6m (62-340 ft)	58m (190 ft)	24.4-103.6m (30-340 ft)
Mixed Clastics	6.1-244.4m (20-802 ft)	44.2m (145 ft)	12.8-163m (42-535 ft)
Balls Bluff Siltstone	6.7-146m (22-479 ft)	35.4m (116 ft)	12.8-99m (42-325 ft)
Triassic diabase (All Areas)	6.7-61m (22-200 ft)	19.2 (63 ft)	9.1-57.9m (30-190 ft)

* Figure adjusted in order to partially compensate for sub-drilling performed to produce a reservoir

\+ After Cady, 1938

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

As originally stated, this report is of a preliminary nature, although it may be used in groundwater resource planning and the development of public and private water systems. It is hoped that in the future, with continued reporting and geologic study, the report can be updated and made more detailed. It should be emphasized that water source plans for specific areas should be supplemented by detailed studies by geotechnical personnel and a plan of test wells. Although several thousand dollars in drilling costs for an inadequate supply of water may seem to be a waste, it is still far less expensive than the development costs of surface supplies.

This report has attempted to briefly explain the geologic diversity, history and geohydrologic environment of Loudoun County. It was stated that the Fault Line and Triassic Basin are the best, potential, water resource areas. The igneous rocks should be avoided, as they are usually dry-to-low producers. The diabase intrusions and feeder dikes are too numerous to be shown on maps of the scale used in the report, and the reader is referred to more detailed maps assembled by U. S. Geological Survey personnel (mentioned in the bibliography).

The relatively-high mineral content of water from the Triassic area may be a limiting factor for industrial use. However, treatment and filtration could correct any problems. Although iron does not appear to be a water problem in any part of the county, the content is lowest in the Triassic sediments. Hardness content is also highest in the Triassic area, though erratic here as elsewhere. Sulfate content appears to be high in the Middleburg area.

The greatest threat to water quality is activity by man. Pollution and overpumping lead to degradation of both quality and quantity. Such items as septic tanks, drainfields, buried fuel and chemical tanks all have a potential for failure. This is particularly true in high-acid soils as are found in Loudoun County. However, even an innocent and beneficial activity such as weed or pesticide spraying can have an adverse effect on groundwater quality. This is because any water-borne contaminant will seek the lowest, gravity-controlled level, and in a porous and permeable medium this means the groundwater table.

In particular, the uncontrolled spread of septic-tank-using-sub-divisions constitutes the greatest present source of groundwater contamination (Geraghty and Miller, 1978). This practice needs to be more closely monitored and possibly restricted. Potential pollution sources, other than those already mentioned, include underground mining, refuse piles and pits, and slurry ponds. Animal feed lots must also be considered.

Unlike with surface waters, there is no easy, or inexpensive, way to clean groundwater. Pollution, regardless of type, normally will stay until it is no longer dangerous, or until filters and treatment facilities are installed at the withdrawal point. Water has been in the ground a long time. In fact, some of the water sampled at the Dulles Airport well by the U. S. Geological Survey personnel (Rubin, personal communication) was age-dated as approximately 16,000 years old. If the water can stay in the ground this long, so could a water-borne contaminant. Can anyone imagine waiting this long, in order to wait-out a contaminant?

The large number of wells in Loudoun County creates a sizeable management problem, as many wells are possessed by second and third generation owners. Oftentimes these owners have no idea of the characteristics of the well on their property. Such information can be as critical to the useability of the property as the house itself; yet few people even think about it. Modern drilling technology has produced better and safer wells than what was possible a generation ago; but a well-informed owner is a critical link to managing and defending a vital resource. It is recommended that an accurate water well completion report be included with the sales documents for all new homes and that old properties be inspected in order to determine the characteristics of existing wells.

APPENDIX A

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR LOUDOUN COUNTY

The computer printout on the following pages lists basic, groundwater quality data available for many of the wells listed in the water well data summary (Appendix B). There are some quality analyses listed for wells not included in Appendix B; however well data is available for these wells and may be obtained by contacting the State Water Control Board's Northern Regional Office in Alexandria or the Headquarters Office in Richmond.

POOR QUALITY

ORIGINAL(S) FOLLOW

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VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR ROCKINGHAM COUNTY

****

THE FOLLOWING LIST OF GROUNDWATER QUALITY DATA SUMMARIZES BASIC DATA OBTAINED FROM ANALYSES OF GROUNDWATER, COLLECTED FROM WELLS AND SPRINGS, WHICH ARE ON PERMANENT FILE IN THE OFFICES OF THE VIRGINIA STATE WATER CONTROL BOARD. ADDITIONAL GROUNDWATER QUALITY INFORMATION FOR MANY OF THESE WELLS AND SPRINGS IS AVAILABLE AND CAN BE OBTAINED BY CONTACTING THE APPROPRIATE REGIONAL OFFICE OR THE BUREAU OF SURVEILLANCE AND FIELD STUDIES AT THE AGENCY HEADQUARTERS IN RICHMOND.

************ EXPLANATION OF PARAMETERS ************

SWCB NO: STATE WATER CONTROL BOARD NUMBER - A SEQUENTIAL NUMBERING SYSTEM USED WITHIN A COUNTY; WHEN REFERRING TO A SPECIFIC WELL USE THIS NUMBER

OWNER AND/OR PLACE: IDENTIFIES ORIGINAL OR CURRENT WELL OWNER AND/OR LOCATION OF WELL.

DATE SAMP: DATE SAMPLED - MONTH AND YEAR IN WHICH WATER SAMPLE WAS COLLECTED.

PH: HYDROGEN ION CONCENTRATION - BASED ON A SCALE OF 1 THROUGH 14. WATER WITH A PH GREATER THAN 7.0 IS CONSIDERED TO BE BASIC OR ALKALINE; THE LARGER THE PH VALUE, THE MORE ALKALINE THE WATER. WATER WITH A PH LESS THAN 7.0 IS CONSIDERED TO BE ACIDIC; THE SMALLER THE PH VALUE, THE MORE ACIDIC THE WATER.

SPEC COND: SPECIFIC CONDUCTIVITY - AN INDICATOR OF THE RELATIVE AMOUNT OF DISSOLVED MINERALS IN WATER; HIGHER VALUES INDICATE GREATER AMOUNTS OF DISSOLVED MINERALS; UNIT OF MEASUREMENT IS MICROMHO

T-DIS SOLID: TOTAL DISSOLVED SOLIDS - INDICATES TOTAL AMOUNT OF DISSOLVED MINERALS IN WATER; UNIT OF MEASUREMENT IS MILLIGRAMS PER LITER

HARDNESS TOTAL: TOTAL HARDNESS - CAUSED BY THE PRESENCE OF CALCIUM, MAGNESIUM, IRON, ZINC , AND OTHER TRACE METALS. UNIT OF MEASURE IS MILLIGRAMS PER LITER.

HARDNESS CA,MG: CALCIUM-MAGNESIUM HARDNESS - INDICATES THAT PORTION OF TOTAL HARDNESS CAUSED BY CALCIUM AND MAGNESIUM, WHICH ARE GENERALLY RESPONSIBLE FOR ALMOST ALL HARDNESS IN WATER. UNIT OF MEASURE IS MILLIGRAMS PER LITER.

THE AMOUNT OF HARDNESS IN WATER WILL AFFECT THE ABILITY OF SOAP TO LATHER OR CLEANSE BECAUSE OF THE TENDENCY OF THE IONS CAUSING HARDNESS TO REACT WITH SOAP. THE HIGHER THE HARDNESS OF WATER, THE MORE DIFFICULT IT IS FOR SOAP TO LATHER.

NOTE: TOTAL HARDNESS IS GENERALLY DETERMINED BY CHEMICAL TITRATION WHEREAS CALCIUM-MAGNESIUM HARDNESS IS GENERALLY DETERMINED BY MATHEMATICAL CALCULATION FROM CHEMICALLY-DETERMINED VALUES FOR CALCIUM AND MAGNESIUM. BECAUSE OF THIS DIFFERENCE IN DETERMINATION, THE CALCIUM-MAGNESIUM HARDNESS VALUES FOR SOME ANALYSES WILL BE LARGER THAN THE TOTAL HARDNESS VALUE.

******** PARAMETERS LISTED BELOW ARE MEASURED IN MILLIGRAMS PER LITER ********

FE: IRON	MN: MANGANESE	CA: CALCIUM
MG: MAGNESIUM	NA: SODIUM	K: POTASSIUM
HCO3: BICARBONATE	SO4: SULFATE	CL: CHLORIDE
	NO3: NITRATE (AS NO3)	

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR LOUDOUN COUNTY

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	ALK	SO4	CL	NO3
28	TOWN OF LOVETTSVILLE	6 73	8.0		120		71	0.02	0.02	16.0	9.2	6.1	3.3	73	8.0	3.0	0.0
28	TOWN OF LOVETTSVILLE	4 71	7.4		123		62	1.40	0.05	11.2	8.4			60	11.7	2.5	
35	TOWN OF LOVETTSVILLE	6 73	8.0	396	274	162	165	0.12	0.11	48.1	11.1	11.3	8.0	143	24.4	18.5	0.0
40	HILLSBORO WATER DEPT	7 73	7.1	54	42	21	20	0.00	0.00	4.8	2.1	2.1	1.4	10	9.1	4.0	0.9
40	HILLSBORO WATER DEPT	3 71	5.9		50	32	18	0.08	0.02	7.2	0.2	1.8	1.5	14	13.2	3.0	1.8
42	NOTRE DAME ACADEMY #2	1 69	7.6			97		0.25	0.18					93		2.0	0.0
46	TOWN OF ALDIE	6 71	6.3		24	7	5	0.32	0.02	1.2	0.7	1.2	1.1	9	4.4	2.0	1.8
49	LEESBURG	4 71	0.6		293	195		0.01	0.02	64.1		7.3	3.2	130	12.4	11.5	31.0
56	EARTH PRODUCTS	5 74	7.9	229			114	0.10		26.0	12.0	40.0	0.3	107		7.0	5.3
57	DRESDEN FARM	5 74	7.4	198			124	0.10		30.0	12.0	16.0	0.4	90		7.0	5.8
58	DRESDEN FARM	5 74	7.1	344			192	0.10		54.0	14.0	50.0	4.2	108		21.0	18.6
59	P R PEARSON	5 74	8.0	427			243	0.10		48.0	30.0	14.0	0.7	201		5.0	20.4
60	W M WALKER	5 74	6.7	146			66	0.10		15.0	7.1	8.3	0.8	26		6.0	10.6
61	W L JAMES	5 74	5.5	27			14	0.10		4.0	1.2	4.0	0.5	6		2.0	3.5
62	H BERNHOUSE	5 74	7.9	271			168	0.10		46.0	13.0	5.1	0.7	133		3.0	10.6
63	G W FLETCHER	5 74	8.0	317			183	0.10		49.0	15.0	4.2	0.9	152		3.0	12.4
64	D HUNT	6 74	6.2	95			33	0.10		9.0	2.7	9.0	6.9	25		0.0	5.8
65	R JAMES	6 74	6.8	150			71	0.10		17.0	7.0	9.0	7.2	60		4.0	3.5
66	W R HARDY	5 74	6.9	153			72	0.10		20.0	5.6	10.0	3.8	43		5.0	12.8
67	JAMES CONARD	5 74	6.3	198			79	0.10		18.0	8.4	11.0	3.9	22		11.0	63.8
68	E V FARINHOLT	5 74	7.0	115			57	0.20		13.0	6.0	3.0	2.3	54		1.0	3.5
69	UNISON CHURCH	7 74	6.7	462			213	1.00		61.0	14.9	25.3	5.8	125		82.0	6.2
70	K R BLAIR	7 74	7.0	157			85	0.10		25.0	5.7	7.5	1.5	66		4.0	15.9
71	R I JENKINS	7 74	6.6	148			88	1.70		23.0	7.5	10.5	4.0	59		2.0	8.0

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR LOUDOUN COUNTY

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL CA,MG	FE	MN	CA	MG	NA	K	ALK	SO4	CL	NO3
72	DR DIAMANT	7 74	6.0	89		51	0.20		15.0	3.5	5.5	2.4	26		5.0	18.2
73	C W MCINTOSH	6 74	7.1	620		379	0.10		78.0	45.0	15.5	2.1	310		17.0	21.3
74	C S PEARSON	6 74	7.5	450		299	0.10		90.0	18.2	18.3	1.7	272		14.0	3.5
75	W BELEU	6 74	7.3	410		225	0.10		36.0	33.0	37.5	2.5	192		29.0	15.5
76	H J MEYLE	6 74	7.5	440		288	0.10		63.0	32.0	18.0	2.0	238		30.0	
77	J B ELLISON	6 74	6.8	375		189	0.10		46.0	18.2	17.3	15.8	135		16.0	
78	J A MORELAND	7 74	7.2	210		156	0.20		40.0	13.7	9.0	4.2	119		12.0	1.3
79	J A ATWELL	7 74	7.9	198		119	0.10		39.0	5.5	6.0	2.4	92		6.0	0.4
80	C ATHEY	7 74	8.1	270		172	0.10		43.0	15.9	6.8	1.0	129		13.0	20.4
81	H SHOTWELL	7 74	7.9	580		340	0.10		105.0	19.2	12.8	0.5	254		16.0	20.8
82	H COLBERT	7 74	7.0	225		96	2.10		23.0	9.6	21.2	6.2	110		16.0	0.0
83	A WILLIAMS	8 74	7.5	360		197	0.10		66.0	8.0	13.3	0.6	144		10.0	46.5
84	R FOX	8 74	7.4	260		151	0.10		52.0	5.4	6.3	0.5	128		5.0	13.7
85	H P HANEY	7 74	7.3	1300		635	0.10		165.0	54.5	46.5	1.3	177		12.0	0.4
86	BUSH	7 74	7.3	720		426	0.10		115.0	34.0	24.5	1.1	273		7.0	1.3
87	J R HARRISON	7 74	7.6	500		282	0.10		82.0	19.0	29.3	0.5	258		20.0	13.7
88	J FOUCHE	7 74	7.3	580		336	0.10		73.0	37.5	23.8	0.8	233		26.0	22.6
89	A ANDERSON	7 74	7.4	450		265	0.10		77.0	17.8	15.0	1.0	180		19.0	18.6
90	ROBERT THOMPSON	10 74	7.8	372		232	0.10		71.0	13.4	14.7	0.1	212		7.0	1.3
91	ALFRED L PHILLIPS	1 75	7.0	125	90	83	1.10		24.0	5.8	2.6	0.8	77	0.0	3.0	0.9
92	HARKNESS	1 75	6.6	112	72	72	0.10		21.0	4.8	2.0	0.8	68	0.0	2.0	0.0
93	LYLE C HARTMAN	1 75	6.9	140	105	81	0.10		22.0	6.5	4.7	1.1	66	0.0	9.0	0.0
94	M G WHITE	1 75	7.7	220	154	137	0.10		38.0	10.3	4.2	0.8	129	0.4	5.0	11.5

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

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SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	ALK	SO4	CL	NO3
95	WILLIAM SAVOPOULOS	2 75	7.7	480	319		223	0.10		66.0	14.2	14.6	0.6	188	20.0	29.0	2.2
96	LEWIS V HALL	2 75	7.9	240	142		118	0.10		32.0	9.5	3.2	0.5	126	0.5	2.0	0.0
97	OBED O BROWN	2 75	7.7	400	254		185	0.10		58.0	9.9	5.0	0.1	198	2.3	9.0	0.4
98	DOUGLAS A PERLICH JR	2 75	7.7	360	224		171	0.10		49.0	11.9	17.5	0.1	190	3.3	6.0	0.4
99	J D THOMAS	3 75	6.7	110	90		58	0.20		12.0	7.0	5.3	0.1	31	14.1	5.0	7.1
100	V L BEGGS	3 75	7.3	270	165		172	0.10		42.0	16.5	8.9	1.5	131	12.8	4.0	13.7
101	WILLIAM JERRELL	3 75	6.8	310	234		157	0.10		33.0	18.3	10.4	1.2	60	36.5	4.0	39.9
102	POTOMAC FARMS	6 76	8.2	282		153	139	0.02	0.00	33.0	13.8	12.0	0.8	151	4.8	5.0	7.1
102	POTOMAC FARMS	6 71	8.1		178	147	147	0.01	0.01	35.5	14.4	11.2	1.1	149	2.4	6.0	8.9
102	POTOMAC FARMS	11 58	7.8				128	0.17		36.1	9.3				2.9	5.3	
103	TOWN OF MIDDLEBURG #1	4 78	7.2	300			126	0.20	0.03	41.0	6.0	9.0	5.0	96		6.0	
103	TOWN OF MIDDLEBURG #1	11 73	7.9	194	183	103	100	0.22	0.04	31.8	5.2	3.5	4.2		33.2	3.0	0.0
103	TOWN OF MIDDLEBURG #1	11 73	7.6	388	325	206	201	0.32	0.36	63.6	10.3	17.5	7.5	160	51.4	26.0	0.4
107	LESBURG-PHILLIPS	4 71	7.6		202	131		0.04	0.01	43.0		2.0	1.3	101	5.7	4.5	39.0
108	LEESBURG-MYERS	4 71	7.6		159	89		0.00	0.00	29.6		2.0	0.7	66	1.7	2.0	19.9
108	LEESBURG-MYERS	2 70	7.3		88	90	90	0.03	0.00	28.8	4.5	7.5	0.5	77	0.0	3.0	7.1
109	U S HUMANE SOCIETY	7 71	8.1		194	106	99	0.04	0.18	28.2	7.0	8.0	6.1	103	13.0	10.0	0.0
109	U S HUMANE SOCIETY	4 69	7.7		179	104	100	0.03	0.02	30.4	6.1	9.7	7.3	102	20.0	9.5	0.0
120	FOXCROFT SCHOOL	8 78	7.7	209			74	0.00		20.0	6.0	7.0	2.0	71		5.0	
153	THOMAS A LYNCH	8 78	7.5	511			215			45.0	25.0	19.0	2.0	174		32.0	
154	R L ALLDER	8 78	6.2	247			81	0.10	0.03	18.0	9.0	10.0	3.0	16		12.0	
155	CHANTILLY	8 78	7.6	314			148			38.0	13.0	16.0		153		4.0	
157	LOUDOUN CO.	8 78	7.9	231			105			34.0	5.0	6.0	1.0	78		7.0	
161	LINCOLN RT 722	2 78				108		0.30	0.18								
164	JAMES H HOUGH	3 78	68.0	446			140	0.30	0.02	35.0	13.0	35.0	6.0			34.0	
165	MARION F HOUGH	3 78	6.6	293			96	0.60	0.02	22.0	10.0	19.0	11.0			24.0	

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR LOUDOUN COUNTY

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	ALK	SO4	CL	NO3
166	CHARLES HUMMER	3 78	7.6	250			120	0.20	0.02	32.0	10.0	11.0	3.0			9.0	
171	PLEASANT VALLEY UMC	8 78	7.7	330			149			37.0	14.0	11.0	1.0	139		12.0	
174	CARROLL MILBOURNE	2 78				214			0.79								
175	SARAH BUXLEY	2 78				164											
177	LEE WILLIAMS	4 78	6.9			282								237	9.0	26.0	14.2
182	FOXCROFT SCHOOL	4 78	7.3	320			136	3.20	0.04	45.0	6.0	7.0	3.0	84		2.0	0.0
188	WALTER H MCDERMITT	5 78	7.0	639			304	0.00	0.01	76.0	28.0	18.0	0.0	237		46.0	8.0
189	L B JAMES	5 78	7.4	513			246	0.00	0.00	74.0	15.0	12.0	0.0	223		16.0	0.0
190	CAREY	5 78	7.1	571			262	0.70	0.00	59.0	28.0	16.0	1.0	223		25.0	3.1
229	DAVID BOWEN	6 78	7.2	440			218	0.00	0.00	61.0	16.0	7.0	5.0	162		0.0	17.7
231	EVERETT W LOWE	6 78	6.7	199			85	0.30	0.00	21.0	8.0	5.0	1.0	44		9.0	13.3
247	S W MONROE	7 78	6.5				45			10.0	5.0	1.0	3.0	51		1.0	
248	JOE BENNET	7 78	6.4				36	0.10		8.0	4.0	2.0	2.0	41		1.0	
265	DOUGLAS MYERS	7 78	7.2				101	1.90	0.04	29.0	7.0	21.0	6.0	110			5.3
266	ALEXANDER SWENEY	7 78	6.9				331	0.90	0.05	80.0	32.0	50.0	3.0	184			61.7
270	N E COPELAND	7 78	6.8				77	0.50	0.01	21.0	6.0	7.0	3.0	80		2.0	
272	DONALD T VIRTS	7 78	7.3	181		72	77	0.90	0.12	23.0	5.0	6.0	5.0	75		3.0	
273	RICHARD ROGERS	7 78	7.9	187		80	86	0.10	0.04	28.0	4.0	8.0	5.0	90		1.0	0.0
275	GEORGE SHANNON	7 78	6.5				76			19.0	7.0	12.0	3.0	25		20.0	
276	WILLIAM C BENDER	7 78	6.5			146	159			44.0	12.0	19.0	2.0	25		18.0	
279	EDWIN CREEL	7 78	7.8	477			280			68.0	27.0	15.0		226		20.0	
281	JOSEPH PRENDERGAST	7 78	6.0	169			52		0.05	11.0	6.0	8.0	3.0	17		11.0	
285	JAMES KAYLOR	7 78	7.0	307			152	9.80	0.54	43.0	11.0	9.0	2.0	108		41.0	

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR   LOUDOUN COUNTY

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	HARDNESS CA,MG	FE	MN	CA	MG	NA	K	ALK	SO4	CL	NO3
363	CLATTERBUCK	8 78	7.6	215			78	0.10	0.02	20.0	7.0	9.0	1.0	44		13.0	
373	H W ALEXANDER	8 78	7.9	662		336	364	0.30	0.02	110.0	22.0	13.0	2.0	302		6.0	
374	DANIELS	8 78	7.1	175		76	70			20.0	5.0	7.0	2.0	39		6.0	
375	WILLIAMS	8 78	7.7	213		56	61			18.0	4.0	18.0		60		5.0	
386	GOLDEN'S WELL	9 78		865		301	330	0.80	0.04	96.0	22.0	36.0	7.0			107.0	

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

APPENDIX B

SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

The computer printout on the following pages lists basic well data for wells in Loudoun County. This printout is updated frequently to include information from new Water Well Completion Reports and old well records. The former is being submitted by water well drillers and the latter is found by State Water Control Board personnel. The information under the heading "Aquifer" may be cross-referenced with Table 2, Chapter III.

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

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THE FOLLOWING LIST OF WELL DATA SUMMARIZES BASIC DATA OBTAINED FROM WATER WELL COMPLETION REPORTS WHICH ARE ON PERMANENT FILE IN THE OFFICES OF THE VIRGINIA STATE WATER CONTROL BOARD. ADDITIONAL INFORMATION FOR MANY OF THE WELLS IS AVAILABLE AND CAN BE OBTAINED BY CONTACTING THE APPROPRIATE REGIONAL OFFICE OR THE BUREAU OF WATER CONTROL MANAGEMENT AT THE AGENCY HEADQUARTERS IN RICHMOND.

************ EXPLANATION OF PARAMETERS ************

SWCB NO: STATE WATER CONTROL BOARD NUMBER - A SEQUENTIAL NUMBERING SYSTEM USED WITHIN A COUNTY; WHEN REFERRING TO A SPECIFIC WELL USE THIS NUMBER

OWNER AND/OR PLACE: IDENTIFIES ORIGINAL OR CURRENT WELL OWNER AND/OR LOCATION OF WELL

YEAR COMP: YEAR IN WHICH WELL CONSTRUCTION WAS COMPLETED

LOG: TYPE OF LOG ON FILE FOR WELL; D = DRILLERS, E = ELECTRIC, G = GEOLOGIC/GAMMA GEOPHYSICAL, L = INTERVIEW LOCATION FORM, M = QUALITY MONITORING WELL,

ELEV: ELEVATION - MEASURED IN FEET ABOVE MEAN SEA LEVEL

TOTAL DEPTH: TOTAL DEPTH DRILLED, IN FEET, WITH RESPECT TO LAND SURFACE

BEDROCK: DEPTH TO BEDROCK, IN FEET, WITH RESPECT TO LAND SURFACE

CASING: MAXIMUM AND MINIMUM DIAMETER OF CASING, IN INCHES, USED IN WELL

DEVEL ZONE: DEVELOPED ZONE - INTERVALS, IN FEET, WHERE AQUIFERS TAPPED AND/OR SCREENED

AQUIFER: WATER-BEARING UNIT; ABBREVIATIONS USED INDICATE GEOLOGIC AGE OF UNIT AND ARE CONSISTENT WITH TABLE 2 AND GENERALIZED GEOLOGIC MAP OF LOUDOUN COUNTY IN TEXT

STATIC LEVEL: DEPTH, IN FEET, TO WATER WITH RESPECT TO LAND SURFACE; MEASUREMENTS TAKEN WHEN WELL IS NOT PUMPED AND ARE GENERALLY THOSE RECORDED ON COMPLETION DATE

YIELD: REPORTED OR MEASURED PRODUCTION, IN GALLONS PER MINUTE

DRAWDOWN: DIFFERENCE, IN FEET, BETWEEN STATIC LEVEL AND PUMPING LEVEL; I.E., REPORTED OR MEASURED DROP, IN FEET, IN WATER LEVEL DUE TO PUMPING

SPEC CAPAC: SPECIFIC CAPACITY - YIELD PER UNIT OF DRAWDOWN EXPRESSED AS GALLONS PER MINUTE PER FOOT OF DRAWDOWN

HRS: HOURS - DURATION OF PUMP TEST, IN HOURS, FROM WHICH THE PRECEDING THREE ITEMS WERE DERIVED

USE: USE OF WATER OR WELL UNDER CONSIDERATION; DOM = DOMESTIC, PUB = PUBLIC, GOV = GOVERNMENT, IND = INDUSTRIAL, COM = COMMERCIAL, INS = INSTITUTIONAL, ABD = ABANDONED, DST = DESTROYED, IRR = IRRIGATION, RCH = ARTIFICIAL RECHARGE

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

****

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
1	USGS-MORRIS	68	G	330	210	9				TRBF	210	20				PUB
2	USGS-MYERS #1	68	G	355	250	16				TRLC	250	5				PUB
3	USGS-MYERS #2	68	G	345	285	14				TRLC	285	5				PUB
4	USGS-MYERS #3	68	G	370	350	47	7	61	64	TRLC	28	251	9	27.88	4	PUB
5	CRIDER & SHOCKEY	64	D	280	140	13	5	28	29	TRBF	20	4				COM
6	H B HARRIS	38	D		248	18	6			CPCC	61	2	187	.01		DOM
7	HARRY MCDERMITH	65	D	475	300	56	5	80	83	CPCC	57	3				DOM
8	DUNCAN H READ	32	D	449	696	4	10			PCM	28	3	162	.01	1	DOM
9	DUNCAN H READ	32	D	449	271	4	8			PCM	80	10	117	.08	48	DOM
10	W C STEVENSON	29	D	500	357	28	8			PCM		16			12	DOM
11	FREDERICK M. WARBURG	37	D	450	161	8	8			PCM	43	3	88	.03	48	DOM
12	LARRY ESTEP	78	D	400	175	9	6			TRBF	45	4				DOM
13	T G SLATTER & SON INC	78	D	430	185	22	6			PCMA	38	8	168	.04	2	DOM
14	A T & T	63	D	1410	491	6	6			CH	68	2	423		3	DOM
15	TOWN OF HAMILTON #3	69	D	490	242	12	7	55	56	PCM	10	3				PUB
16	TOWN OF HAMILTON #4	69	D	500	125	12	7	90	93	PCM	23	41	64	.64	24	PUB
17	R M SEXTON	53	D	400	130	35	6	90	95	CPCS	35	3				DOM
18	ELIZABETH BOLING	50	D	575	120		6	120	120	PCM	38	10	80	.12		DOM
19	A T & T #3	63	D	690	289		7			PCG	14	25	115	.21	27	COM
20	PRAYNE & PHIBES	52	D	425	177	60	8	150	150	TRLC	77	4			12	IRR
21	METHODIST BOYS CAMP	49	D	450	53	30	6	52	52	CPCS	20	2			1	INS
22	OBS WELL #22 A T & T	63	E	920	516	26	6			CW	62	9	145	.06	20	COM
23	METHODIST BOYS CAMP	49	D	450	143	19	6			CPCS	40	8	103	.07	3	INS
24	CHARLES W SYDNOR	52	D	448	93	21	6	80	93	CPCC	13	10	40	.25	1	DOM
25	W E FLETCHER	49	D	500	106	30	6	101	101	PCM	16	9				DOM
26	JOHN GOODWIN	49	D	322	60	6	6			TRBB	7	5				DOM
27	A H BOWMAN	50	D	285	167	14	6	150	167	TRMS	50	7				DOM
28	TOWN OF LOVETTSVILLE	70	D	495	500		6			PCM		30				PUB
29	JAMES FOWLER	70	D	500	300	30	6			PCM	15	180				DOM
30	TOWN OF HAMILTON #9	70	D	475	386	30	7	155	161	PCM	6	42	141	.29	24	PUB
31	J LYNN CORNWELL INC	70	D	495	397	4	7	307	308	PCM	28	25				DOM
32	TOWN OF HAMILTON #7	70	D	500	297	6	6	260	270	PCM	67	29	200	.14	77	PUB
33	TOWN OF LOVETTSVILLE	71	D	495	400	10	6	240	260	PCM	30	80			12	PUB
34	ARCOLA ELEMENTARY SCH	71	D	350	360		6			TRBB		20			1	PUB
35	TOWN OF LOVETTSVILLE	71	D	495	200	31	6	170	175	PCM	42	131	195	.67	72	PUB
36	XEROX CORP	71	D	332	479	9	6			TRBB	8	62				COM
37	TOWN OF HAMILTON #1	49	D	512	210		6			PCM		18				PUB
38	TOWN OF HAMILTON #2	56	D	512	413		6			PCM		22				PUB
39	MIDDLEBURG WATER #2	72	L	400	350		6			PCM		150				PUB
40	FRANK MACHNICK JR	78	D	430	210	25	6			PCG	32	12	185	.06	2	DOM
41	VA DEPT OF HIGHWAY	63	D	555	400	60	6			CPCS		6				DOM
42	NOTRE DAME ACADEMY	68	D	495	262		6			PCG	180	30	20	1.50		PUB
43	J LYNN CORNWELL #1	66	L	538	300		5			PCM	28	20				DOM
44	J LYNN CORNWELL #2	66	L	500	280		5			PCM	4	100				DOM

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
45	J LYNN CORNWELL #3	66	L	512	390		5				PCM	15	50				DOM
46	CLAUDE CHURCH	78	D	405	85	35	6				TRBF	60	8				DOM
47	TOWN OF HAMILTON #6	62	D	491	248	27	6		140		PCM	10	8				PUB
48	LEESBURG	58	L	351													PUB
49	LEESBURG-PAXTON	62	L	345	400		10				TRLC	70	480	25	19.20		PUB
50	WILLIAM BREHM	78	D	500	190	8	6				PCM	37	20				DOM
51	TOWN OF HAMILTON #7		L	491	154						PCM		30				PUB
52	JOHN ROBISON	78	D	500	170	20	6				PCG	42	50				DOM
53	LOUDOUN DAIRY INC		L	265							TRBB						PUB
54	LOUDOUN CO SCHOOLS	72	D	495	100	4	6				PCM	10	50			5	PUB
55	TRI-STATES ASSOC	74	D	530	310	10	7		293	295	PCM	26	80	176	.45	24	DOM
56	EARTH PRODUCTS	73	M	395							TRBF						COM
57	J WILSON		M	485							CPCS						DOM
58	J WILSON		M	455	500						CPCS						DOM
59	PR PEARSON	59	M	315	400						TRLC						DOM
60	WM WALKER		M	640							CPCC						DOM
61	W L JAMES	61	M	653	105						CW		25				DOM
62	H BARNHOUSE	57	M	382							TRLC						DOM
63	G W FLETCHER	71	M	240	125						TRLC		20				DOM
64	D HUNT	62	M	562							CPCC						DOM
65	R JAMES		M	435							PCM						DOM
66	W R HARDY	70	M	575	200						PCG	90					DOM
67	J CONARD	54	M	425	70						CPCS						DOM
68	E V FARINHOLT	73	M	485							PCM						DOM
69	UNISON CHURCH		M	484							PCM						INS
70	K R BLAIR	72	M	532	140						PCM						DOM
71	R I JENKINS	74	M	472	250						PCM						DOM
72	DR. DIAMANT		M	410							PCM						DOM
73	C W MCINTOSH	63	M	409	105						TRD						DOM
74	C S PEARSON		M	312							TRBB						DOM
75	W BELEU		M	390	65						TRBB						DOM
76	H J MEYLE		M	340							TRB						DOM
77	J B ELLISON		M	363							TRBF						DOM
78	J A MORELAND		M	459	80						PCM						DOM
79	J A ATWELL		M	515	140						PCM						DOM
80	C ATHEY		M	300							TRLC						DOM
81	H SHOTWELL	67	M	335							TRBB						DOM
82	H COLBERT	70	M	520			4				PCG						DOM
83	A WILLIAMS	68	M	385							TRBF						DOM
84	R FOX	59	M	362							TRBF						DOM
85	H P HANEY		M	280	200		4				TRBB						DOM
86	BUSH		M	324							TRBB						DOM
87	J R HARRISON		M	292							TRBB						DOM
88	J FOUCHE		M	358	22						TRBB						DOM

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
89	A ANDERSON	67	M	385							TRB						DOM
90	ROBERT THOMSON		M	290	175						TRMS						DOM
91	ALFRED L PHILLIPS		M	375	121						TRBF						DOM
92	HARKNESS		M	400							TRBF						DOM
93	LYLE C HARTMAN		M	374	100						TRBF						DOM
94	M G WHITE		M	360	60						TRBF						DOM
95	WILLIAM SAVOPOULOS	66	M	400							TRB						DOM
96	LOUIS V HALL	73	M	470	300						TRLC		9				DOM
97	OBED O BROWN		M	234	194						TRMS		24				DOM
98	DOUGLAS A PERLICH	59	M	225							TRMS						DOM
99	J D THOMAS		M	750	80						CPCS		25				DOM
100	V L BEGGS	61	M	530	190						CPCC						DOM
101	WILLIAM JERRELL		M	455	90						CPCC						DOM
102	C CARE-POTOMAC FARMS			210	325						TRBB						PUB
103	TOWN OF MIDDLEBURG	56	L	475	778		6				PCM		76				PUB
104	TOWN OF LEESBURG #1		L	345	360		10				TRLC		60				PUB
105	TOWN OF LEESBURG #2		L	345	152		6				TRLC		40				PUB
106	LEESBURG-FIREMAN WELL	54	L	335	296		12				TRLC		160				PUB
107	LEESBURG-PHILLIPS	56	L	342	328						TRBF	47	300				PUB
108	LEESBURG-MYERS	73	D	380	350		7				TRLC	29	300	50	6.00	24	PUB
109	HUMANE SOC OF US		L	410							PCM						INS
110	LOUDOUN CO SCH BOARD	75	D	375	240	82	6				TRBF	26	30	3	10.00	120	INS
111	ANDOVER MEADOWS #1	75	D	370	500	16	10	6			TRLC	14	1	500		2	PUB
112	ANDOWER MEADOWS #2	75	D	370	540	28	6	6			TRLC	15	1	540		4	PUB
113	FOXCROFT SCHOOL #1	30	L	480	999		12	8			PCM	190	25	60	.41		PUB
114	FOXCROFT SCHOOL #6	66	L	500	360	9	6				CPCS	1	32	280	.11	8	INS
115	FOXCROFT SCHOOL #7	72	L	520	500		6				PCM	60	12				INS
116	HAMILTON KNOLLS #2	76	D	530	165	55	4		80	160	PCM	20	7	81	.08	72	INS
117	TOWN OF HAMILTON #10	76	D	491	725	30	6		365	370	PCM	2	25	243	.10	48	PUB
118	HAMILTON ACRES 2 #6	76	D	515	400	20	6		240	260	PCM		24	250	.09	72	PUB
119	HAMILTON ACRES 2, #3	78	D	510	400	20	6		240	270	PCM	30	60	240	.25	72	PUB
120	RUSSLE SEXTON		L	430	15		60				PCG	3					DOM
121	WALKER & CLARKE BLD	78	D	510	90	50	6				CPCS	48	15	72	.20	2	DOM
122	JAMES PIERSON	65	M	535	135						PCM						DOM
123	JEFFREY WARREN	76	D	415	160	24	6				PCM	20	50				DOM
124	HAMILTON KNOLLS #4	76	D	500	230	70	6				PCM	31	55	46	1.19	48	PUB
125	HAMILTON KNOLLS #3	76	D	505	400	53	6				PCM						PUB
126	F S MASTERO	77	D	455	195	15	6				PCM		8			1	DOM
127	RALPH C MITCHELL	77	D	592	255	30	6				PCG	60	6			2	DOM
128	KENT MARSH	76	D	430	180	10	6				PCM		15				DOM
129	TOM DELASHMUTT	76	D		500	21	6					20	1				DOM
130	TOWN OF HAMILTON #11	77	D	535	400	38	7				PCM	23	100	69	1.44	48	PUB
131	THOMAS L KENT	77	D	365	405		6				TRBB	35	2			1	DOM
132	JOHN WILKINS	77	D	495	175	26	6				PCG	40	30			3	DOM

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SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
133	TOWN OF LEESBURG#1	77	D	475	550	35	6				CPCC	30	15	550	.02	8	PUB
134	TOWN OF LEESBURG #2	77	D	410	550	20	6				CPCC	20	50	550	.09	8	PUB
135	TOWN OF LEESBURG #3	77	D	345	535	2	6				TRBF	10	20	535	.03	3	DOM
136	TOWN OF LEESBURG #4	77	D	325	615	20	6				TRBF	35	15	615	.02	8	DOM
137	TOWN OF HAMILTON	76	D	535	380						PCM						PUB
138	DUDLEY & ELIZ BUNN	78	D	400	250	17	6				CPCC	42	15	129	.11	2	DOM
139	EUGENE D GOFF	78	D	350	145	70	6				TRBF	42	12	123	.09	2	DOM
140	J R & ANN BURNETT	77	D	1040	540		6				CPCC	60	20			1	DOM
141	CHESTER A KMAK	78	D	410	250	25	6				TRBF	40	60	235	.25	3	DOM
142	THOMAS P JORDAN	78	D	365	340	25	6				TRB	45	6	300	.02	3	DOM
143	J R & ANN BURNETT	77	D	690	540		6				CPCC	100	20			1	DOM
144	HUDDLE RESTAURANT	60	L	500							PCM						PUB
145	JIMMY COX GCF34	78	D	485	620		6				CPCS		1				DOM
146	MARK REED	77	D	513	345		6				PCM						DOM
147	PAUL ROSS	77	D	420	100	6	6				CW		50				DOM
148	DAVID HUBERT	77	D	590	125	4	6				CW		50				DOM
149	LARRY A PATRICK	77	D	600	250	15	6				PCG	47	10			3	DOM
150	JOHN RICCA	77	D	340	240	5	6				TRB		30	215	.13	3	DOM
151	ED FELLOWS	78	D	460	325	20	6				PCM	32	6	300	.02	2	DOM
152	C M ZACK	77	D	392	160	10	6				TRBF	40	30			3	DOM
153	T A LYNCH	75	L	330	290		8				TRB	35	8				DOM
154	R L ALLDER		L	375	62						TRB						DOM
155	CHANTILLY C S	60	L	350	80						TRBB		2				COM
156	J LYNN CORNWELL INC	66	L	520	390		5				PCM		5				DOM
157	JOHN CLATTERBUCK		L	495	125		6				PCG						DOM
158	BLUEMONT GEN STORE		L	712							CPCC						COM
159	UNKNOWN		L	710							CPCC						DOM
160	E H DEBUTTS	78	D	430	295	22	6				PCM	47	5	278	.01	3	DOM
161	HILLTOP GARDEN CENTER		L	500	120						PCM						COM
162	BILL RAPSON	78	D	310	330	30					TRLC		5			1	DOM
163	LEESBURG COUNTRY CLUB	78	D	325	160	10	6				TRLC	26	100	100	1.00	3	PUB
164	JAMES H HOUGH	66	L	745	175		8				PCG		12				DOM
165	MARION HOUGH	65	L	745			8				PCG						DOM
166	CHARLES M HUMMER	63	L	580	80		6				PCG	70	40				DOM
167	RAY JACKSON	78	D	375	290	20	6				PCM	25	2	280		3	DOM
168	HOWAR BACUM	78	D	480	295	18	6				PCM	50	10	275	.03	3	DOM
169	RALPH N IVES	78	D	485	200	16	6				PCM	50	10	180	.05	3	DOM
170	ELMORE CONST CO	78	D	365	235	38	6				PCM	45	3	220	.01	3	DOM
171	PLEASANT VALLEY UMC	48	L	300	40						TRBB						INS
172	STANLEY E RUSSELL	78	D	700	245	30	6				PCG	40	8	230	.03	3	DOM
173	BLUE RIDGE CHASE 2#11	78	D	1310	230	15	6				CPCC	35	5	200	.02	2	DOM
174	CARROL MILBOURNE	67	L	500	150		6				PCM						DOM
175	SARAH BOXLEY	48	L	605	230						PCM						DOM
176	VICA	78	D	375	725	28	6				TRLC	45	10			48	COM

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SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
177	LEE WILLIAMS	72	L	350	300		6			CPCS	40					DOM
178	EDWARD B DAWSON	78	D	345	205	8	6			PCM	45	10	192	.05	2	DOM
179	J R HUMMER	38	L	505	28		48			PCM						DOM
180	J R HUMMER	50	L	505	65		6			PCM						DOM
181	FOXCROFT SCHOOL #3		L	455	450		6			CPCS	90	30				INS
182	FOXCROFT SCHOOL #8	76	D	540	550	25	6			PCM	45	21	470	.04	48	INS
184	MOORCONES SUBD #5	78	D	512	100	22	6			PCM	30	30	80	.37	2	PUB
185	MOORCONES SUBD #15&16	78	D	490	115	15	6			PCM	30	10	100	.10	3	PUB
186	MOORCONES SUBD #17&18	78	D	475	130	22	6			PCM	40	50	120	.41	3	PUB
187	ALAN CAINE	77	D	490	450		6			CPCC	60	2			2	DOM
188	WALTER H MCDERMITT	58	L	212	165		6			TRBB						DOM
189	L B JAMES	61	L	212	110		6			TRBB	20					DOM
190	CAREY	55	L	202	120		6			TRBB	20					DOM
191	RALPH CURTIS	74	L	370	350		8			PCM	40	8				DOM
192	V B BORAH	74	L	490	350		6			PCM		8				DOM
193	SELBY L WILLIAMS	46	L	330	60		6			PCM	12	1				DOM
194	R V BROWN	70	L	330	210		6			PCM	28	20				DOM
195	PAINTER / FLETCHER	51	L	330	127		6			PCM	57	5				DOM
196	AL WILT	58	L	360			24			CPCS						DOM
197	HELENA HERNDON	78	D	430	205	15	6			CPCC	40	8	185	.04	2	DOM
198	RAMON J PIKE	78	D	460	230	8	6			PCM	35	50	205	.24	2	DOM
199	DONALD F FOTH	78	D	532	110	10	6			PCM	30	10	80	.12	2	DOM
200	MARK E CHAMBERLAIN	78	D	390	300	45	6			PCM	40	10	270	.03	2	DOM
201	WILLIS H MARTIN JR	78	D	405	203		6			TRLC	50	15	175	.08	2	DOM
202	LEAH REISNER	78	L	350	120		6			TRBF	40	8				DOM
203	GEORGE P ROLLISON	78	L	420	180		6			PCM		7				DOM
204	C J MOORE		L	650	400	18	6			CPCC		4				DOM
205	EDWARD M COOK		L	490	120		6			PCW		30				DOM
206	LOUIS & SARAH HERTZOG	78	L	620	400		6			CPCC		4				DOM
207	SYCOLINE 1ST BAPT CH	78	L	382	240		6			TRBF		20				INS
208	R J DEHART	78	L	320	160		6			PCG		25				DOM
209	HERBERT H FARRIS	78	L	250	60		6			TRLC		20				DOM
210	W GREY PRICE	78	L	350	220	2	6			TRBF		8				DOM
211	HUTCHISON & MASON	78	L	305	300		6			TRMS		2				DOM
212	M N LYON	78	L	560	300	5	6			CPCC		2				DOM
213	CHARLES MCGEHEE	78	L	570	200	8	6			PCM		8				DOM
214	JAMES T GARDELLA	78	L	320	150	20	6			CPCC		8				DOM
215	VEVA BORAH	78	L	320	350		6			CPCC		8				DOM
216	JOHN F MCOLONEY	78	L	510	250		6			CPCC	26	32				DOM
217	GLENN A TEUKSBURY	78	L	670	75		6			CPCC		22				DOM
218	LEONARD C BOWMAN	78	L	490	525		6			PCM		5				DOM
219	PIEDMONT LAND CO.	78	D	565	400	8	6			PCM	35	4	385	.01	2	DOM
220	E V FINN(42,PARC 56A)	78	D	592	160	8	6			CPCS	35	6	145	.04	2	DOM
221	RIDDLE CONST	78	D	235	145	25	6			TRBB		6				DOM

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SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
222	HERBERT C BOHRER	78	D	290	205	10	6				TRLC		60			1	DOM
223	CATHERINE LOY	38	L	330	15		48				CPCC						DOM
224	TOM & KATHY KREITZER	72	L	320	250						CPCC						DOM
225	CLARK BAKER	50	L	340	63		4				CPCC	6	5				DOM
226	CLARK BAKER JR	55	L	340	60		4				CPCC	8	5				DOM
227	ALLEN E BAKER	70	L	350	300		6				CPCC	20	1				DOM
228	NORA STREAM		L	410							CPCC						DOM
229	DAVID BOWEN		L	390	275		8				CPCC		11				DOM
230	GLENDEN L WANNER	71	L	340	150		6				CPCC		18				DOM
231	EVERET W LOWE	75	L	400	200		6				CPCC	40	15				DOM
232	L E MERCHANT		L	300			6				CPCC						DOM
233	HILDA B HATTON	65	L	520	115						CPCC		18				DOM
234	MARGARET DIETZ	77	L	420	500		6				CPCC		1				DOM
235	WILLIAM FLACK	77	L	460							CPCC						DOM
236	NATALIE WRAGA	68	L	460							CPCC						DOM
237	NATALIE WRAGA	60	L	240							CPCC						DOM
238	CPT TAYLOR	66	L	460	400						CW		2				DOM
239	ROSCOE WINTER	48	L	270	150		6				CW	50	18				DOM
240	FRANCES SIZEMORE	48	L	270	90						CW						DOM
241	WAYNE MCKENNY	48	L	240							CW						DOM
242	ROBERT LEE BIER		L	260							CW						DOM
243	CHRISTENSEN		L	270	260						CW		25				DOM
244	MARTIN		L	240	300						CH						DOM
245	FLORENCE BARNHAUS	77	L	270	350						CH		8				DOM
246	S D GROVES	77	L	250	540		6				CH		2				COM
247	S W MONROE	73	L	310	230		8				CH		20				DOM
248	JOE BENNET	76	L	310	165		6				CH		7				DOM
249	ATHEY	73	L	400	325		6				TRLC	40	25				DOM
250	GEORGE BEEKE	77	L	350	210		6				CH	120	7				DOM
251	CPT K L JEFFREY		L	250							CF						DOM
252	THOMPSON	77	L	385			6				TRLC						DOM
253	CLIFTON S SORRELL	76	L	405	235		6				TRLC		12				DOM
254	WARREN REXRODE	78	D	398	200	29	6				TRD	35	6	180	.03	2	DOM
255	MIDDLEBURG BLDG CO	78	D	475	160	8	6				PCM	38	10	145	.06	2	DOM
256	DAVID LLOYD	78	D	470	415	10	6				PCM	50	5	395	.01	3	DOM
257	NATIONAL BEAGLE CLUB	66	L	500	346		6				CPCC	46	2				INS
258	GLENN CALVIN NORTON	78	D	270	145	10	6				TRBB	40	100	125	.80	3	DOM
259	RICHLAND ACRES #6	78	D	245	200	20					TRMS						PUB
260	PSYCH INST OF WASH DC	77	D	270	140		6				TRLC	18	39	55	.70	48	INS
261	SHOAF	45	L	380	35						PCM						DOM
262	CECIL JENNINGS	60	L	380							PCM						DOM
263	JEWELL	35	L	395	30		36				PCM						DOM
264	GEN & MRS GONSETH		L	390	100						PCM						DOM
265	DOUGLAS MYERS	69	L	380	500						PCM		1				DOM

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
266	ALEXANDER SWENEY	00	L	370	7		36			PCM	4					DOM
267	J T MCCRACKEN SR	68	L	425	175		6			PCM		5				DOM
268	WARREN BOGGESS		L	420			36			PCM						DOM
269	AMARI		L	370	125					PCM		5				DOM
270	N F COPELAND	66	L	235	236					PCM	7	3				DOM
271	DEANE QUINNEY	53	L	535	140		36			PCM						DOM
272	DONALD T VIRTS	50	L	500						PCM						DOM
273	RICHARD ROGERS	76	L	460	300		6			PCM	10	8				DOM
274	GEORGE SHANNON	58	L	430	85		6			PCM	5	15				DOM
275	GEORGE SHANNON	58	L	440	120		6			PCM	10	9				DOM
276	WILLIAM C BENDER	37	L	510	50		48			PCM						DOM
277	VA BEEF CORP	78	D	275	265		6	245	246	TRBB	30	120	255	.47	3	COM
278	HASTENING FARM LTD	78	D	552	210	8	6			PCM	52	50	185	.27	2	DOM
279	EDWIN CREEL	45	L	340	135		6			TRD						DOM
280	H A WRIGHT		L	360						TRBF						COM
281	JOSEPH PRENDERGAST		L	340			6			TRBF		4				DOM
282	JOSEPH PRENDERGAST	76	L	305	230		6			TRBF		25				DOM
283	JAMES S KAYLOR		L	320	40		48			CW						DOM
284	JAMES S KAYLOR	60	L	310	65		8			CW						DOM
285	CHURCH OF REDEEMER	56	L	320	65		10			CW						INS
286	AUBREY VIRTS	78	D	480	140	40	6	130	131	PCM	25	12	130	.09	3	DOM
287	RANDY WATERMAN	78	D	810	445	20	6			CPCC	38	4	420		2	DOM
288	M F ROSE SEC 37, #56B	78	L	625	340		6			CPCC		4				DOM
289	ROBERT BELL	78	D	432	105	20	6			TRBF		60				DOM
290	GROVER CRANDALL 47F-2	78	D	500	270	5	6			CPCC	45	50	255	.19	3	DOM
291	REX H SHUMAKER	78	D	540	600		6			PCM						DOM
292	RICHLAND ACRES #7	78	D	235	205	25				TRMS		15				DOM
293	THOMAS DELASHMUTT	78	D	570	740	22	6			PCM						ABD
294	J G SCHOOLER	77	D	505	500		6			PCM	30	1			2	DOM
295	P ADAMS		L	400	190					TRBF						DOM
296	J STEPHEN WILLIAMS		L	370						TRB						DOM
297	ALFRED WILLIAMS		L	370						TRBF						DOM
298	ALFRED WILLIAMS		L	365						TRBF						DOM
299	WALTER ENTERPRISES		L	400						TRBF						DOM
300	CECIL E TEATS		L	410						TRBF						DOM
301	W B TRITTIPOE		L	350						TRB						DOM
302	THOMAS DELASHMUTT	20	L	370	110		6			TRB						DOM
303	RUDION CANTACUZENE	77	L	395						CPCC						DOM
304	J LINDSEY	77	L	400	150		6	80		PCM		9				DOM
305	PAUL MCDONALD	77	L	400	325		6			PCM		5				DOM
306	DAVID L LIPPS JR	78	D	270	220	15	6			TRB	38	15	192	.07	2	DOM
307	TOWN OF LEESBURG CDW1	78	D	322	115	15	6			TRLC	18	55	78	.70	7	PUB
308	TOWN OF LEESBURG CDW2	78	D	300	145	20	6			TRLC	35	325	72	4.51	48	PUB
309	TOWN OF LEESBURG CDW3	78	D	350	115	55	6			TRLC	29	500	38	13.15	48	PUB

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SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
310	LEESBURG DIZEREGA	78	D	345	500	10	6			TRLC	45	4	475		2	PUB
311	JAMES D TEMPLE	78	D	232	220	28	6			TRBB	48	12	197	.06	2	DOM
312	CONRAD S MALLOY	78	D	212	130	50	6			TRBB	42	30	119	.25	2	DOM
313	MARVIN A WALKER	78	D	730	400	13	6			CPCC	55	2	375		2	DOM
314	J CANTRALL	78	D	590	190	10	6			PCG	42	6	173	.03	2	DOM
315	JOHN W HILL JR	78	D	500	130	27	6			PCM	32	15	115	.13	2	DOM
316	FRANCIS NEELY	78	D	590	115	11	6			PCG	30	25	95	.26	2	DOM
317	DEAN RATHBURN	78	D	700	415	60	6			CPCS	45	7	400	.01	2	DOM
318	L D BURGER	78	D	340	375	6	6			TRBB	50	1	350		2	DOM
319	L D BURGER	78	D	340	460		6			TRBB						DOM
320	B C HAGAMAN	78	D	500	215	40	6			PCM	50	100	180	.55	2	DOM
321	GERALD W HOPPE	78	D	520	265	45	6			PCM	35	6	245	.02	2	DOM
322	RALPH C LAROCK	78	D	500	205	30	6			PCM	30	4				DOM
323	JOHN C MINOGUE	78	D	480	165	21	6			PCM	20	6				DOM
324	LARRY A PATRICK	77	L	560	250		6	232		PCG		10				DOM
325	UNKNOWN		L	1100	100					CW		50				DOM
326	F PAUL GRASSO	77	L	480	500	3	6	360		PCM		2				DOM
327	F JOHN FRANCIS	77	L	505	120		6	100		PCM		20				DOM
328	CHARLES G DWYER	77	L	490	150		6	40		PCM		10				DOM
329	C F SHEPHERD	77	L	500	250		6	48		PCM		3				DOM
330	CLAYTON DAVIS	77	L	520	105	25	6	25		PCM		50				DOM
331	BETTY L MOYERS	76	L	420	100	10	6	70		PCM		6				DOM
332	JOHN A PAYNE	77	L	420	350	12	6	350		PCM		50				DOM
333	WHITE PILLION	77	L	440	160	15	6	140		PCM		15				DOM
334	ANDREW COATES	76	L	420	100		6			PCM		20				DOM
335	ROBERT CUMBERLAND	77	L	410	220	20	6	90		CPCS		5				DOM
136	JEROLD DUBIT	77	L	400	225	7	6	2000		CH		5				DOM
337	JOSEPH MCDOROUGH	78	D	350	190	11	6			PCM	38	8	172	.04	2	DOM
338	JOSEPH MCDOROUGH	78	D	350	400	8	6			PCM	58	1	382		2	DOM
339	DOUGLAS LAWSON	78	L	430	400					PCM		3				DOM
340	MADISON HOUSE	78	D	305	250	30	6			TRLC		30			48	DOM
341	KENNETH B MARSHALL	78	D	485	225	18	6			PCM	38	50	200	.25	2	DOM
342	JOHN DILLON	78	D	495	160	8	6			PCM	35	25	145	.17	2	DOM
343	DURETTE M HUCK		L	610	225			206		PCG		18				DOM
344	THELMA N POORE	77	L	600	190					PCG		10				DOM
345	JAMES W HARRIS	77	L	790	125		6	90		PCG		25				DOM
346	WALTER WILCOX	77	L	870	325		6	75		PCG		3				DOM
347	W W EVERETT	77	L	570	445		6	425		PCG		2				DOM
348	DOUGLAS LAWLER		L	560	200			160		PCG		2				DOM
349	HENRY ROMBERG	77	L	595	220		6	200		PCG		8				DOM
350	JEWLE H DEMYTTENAIRE	77	L	590	220		6			PCM		6				DOM
351	CHARLES HALL	77	L	520	260		6	210		PCM		7				DOM
352	JAMES & MARY CASE	78	L	525	140		6	130		PCM		30				DOM
353	HENRY PLASTER	77	L	635	265		6	250		CPCS		10				DOM

VIRGINIA STATE WATER CONTROL BOARD

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SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
354	WILLIAM DOERKEN	76	L	840	190		6		180		CPCS		6				DOM
355	BRUCE PATTERSON	77	L	1560	350		6		335		CPCS		1				DOM
356	FRANK AMOS	77	L	525	130		6				PCM		15				DOM
357	HENRY RAMEY	77	L	455	250		6		235		PCM		4				DOM
358	R H RANDOLPH	78	L	545	190		6		170		PCM		50				DOM
359	GEORGE HORKAN	77	L	575	145		6		130		PCM		8				DOM
360	WILLIAM S STOKES III	77	L	565	105		6		80		PCM		10				DOM
361	JOHN HANNA	77	L	455	235		6		220		PCG		6				DOM
362	DEAN RATHBUN	77	L	495	235		6		215		PCG		12				DOM
363	CLATTERBUCK		L	610	40						GRGN						DOM
364	FITZWATER		L	490	400						GRGN		5				DOM
365	CHARLES MILLER		L	420	80		6				GRGN						DOM
366	FRED CALHOUN		L	500	40		6				GRGN						DOM
367	HALTERMAN		L	520	100		6				GRGN						DOM
368	OKEY SNYDER		L	520			6				GRGN	120	25				DOM
369	HACKLEY		L	605							GRGN						DOM
370	HESS		L	610	38		6				GRGN	6					DOM
371	JOHN DAVID BUTTS		L	440	60						GRGN						DOM
372	HOWARD BUTTS		L	465	60		24				GRGN						DOM
373	H W ALEXANDER	58	L	280	80		6				TRD	20	20				DOM
374	DANIELS	23	L	330	55		6				TRB	18	50				DOM
375	MR WILLIAMS	59	L	280	193	30	6				TRD		8				DOM
376	B M CARLTON	78	D	380	125	82	6				CPCS		10				DOM
377	R WALTERS-PIEDMONT MT	78	D	410	370	42	6				CPCC	35	15	350	.04	2	PUB
378	JOHN W DEAN	78	D	670	365	8	6				PC	30	2			1	DOM
379	HIDEO IHARA	78	D	340	420	8	6				CPCC		8				DOM
380	BRADLEY M BROWN	78	D	360	165	50	6				CPCS		12				DOM
381	BILLY B JOURNELL	78	D	425	170	9	6				PCMA	32	10	150	.06		DOM
382	INSTITUTE CORP	78	D	485	220	20	6				CPCC	40	15				DOM
383	HENRY M BORGER	78	D	495	265	9	6				PCMA	35	30	230	.13		DOM
384	JAMES GIBSON	78	D	465	190	9	6				PCMA	35	10	165	.06		DOM
385	EMILY VERKOUTEREN	78	D	1155	325	8	6				CPCC	45	3	305			DOM
386	GOLDIN	00	L	480	350						PCMA						DOM
387	CRAWN	73	L	440	125						PCMA						DOM
388	ROBERT F KAN	78	D	600	225	9	6				CPCC	40	30	200	.15		DOM
389	EDWARD BURLING	00	L	475							PCMA						DOM
390	EDWARD BURLING	00	L	500							PCMA						DOM
391	EDWARD BURLING	00	L	455							PCMA						DOM
392	EDWARD BURLING	00	L	495							PCMA						DOM
393	PHILIP E BIRDSONG	78	D	475	205	25	6				PCMA	32	20	185	.10	1	DOM
394	DULLES AIRPORT USGS	59	S	290	1020		14	10			TRN	21					PUB
395	NOAA USGS	42	S	270	405						TRN	17					GOV
396	JACK WESTON	78	D	545	205	18	6				PCMA	42	20	185	.10	1	DOM
397	CARLIN&GLADYS BEAVERS	78	D	475	365	28	6				PCMA	55	15	330	.04	1	DOM

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR LOUDOUN COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
398	DORSEY FURROW	78	D	440	178	130	6				CPCC	80	40			1	DOM
399	EXPRESSWAY CORNER	78	D	270	178	10	6		160		TRN	40	18			1	IND
400	DR J A VAN FLEET	78	D	380	180	15	6				PCMA	35	20	160	.12	1	DOM
401	WT HIGGINS SEC55PAR16	78	D	420	545	8		6			PC	53		543		1	DOM
402	WT HIGGINS SEC55PAR16	78	D	425	425	10		6			PC	46	3	400		1	DOM
403	SWITHERN LLOYD	78	D	450	200	9		6			PCMA	38	10	180	.05	1	DOM
404	WATERFORD STP	76	D	360	400	15		6			PCMA	25	5	225	.02	1	PUB
405	FENTON LOVE & J HOGG	78	D	530	360	11		6			PCMA	38	12	338	.03	1	DOM
406	CLAGGETT SEC36P12L7	78	D	480	165	12		6			PCMA	40	50	140	.35	1	DOM
407	JAMES MOORE(CG DEPUY)	78	D	490	300	9		6			PCMA	46	3	280	.01	1	DOM
408	JIM GILES	78	D	465	210	8		6			PCMA	36	8	190	.04	1	DOM
409	DEFOREST CHUKA	78	D	400	315	14		6			PCMA	46	8	280	.02	1	DOM
410	JOHN HUMPHREY	78	D	745	545	30		6			PC	45	2	500		1	DOM
411	A L HORNING	60	L	530	160	20		6			CPCC		300			1	IRR
412	JAMES R WOODROW	78	D	345	198	10		6	100		TRN	25	2			1	DOM
413	NTHP OATLANDS ESTATES	00	L	290	85			8			TRN						PUB
414	BROWNELL INC	78	D	435	210	93		6	200	205	CPCC		8			1	DOM
415	MILTON GULICK #1	78	D	435	400	8		6			TRI						DOM
416	MILTON H GULICK #2	78	D	435	460	10		6			TRI	420					DOM
417	CURRY			370							TRN						ABD
418	CHILDRENS CENTER #2			440	304			6			CPCC						ABD
419	HONICAN			340							TRN		120				ABD
420	WC WRIGHT #1	78		370	160			6			TRN	26	120			48	ABD
421	SAFEWAY #1	78		335	400			6			TRN						ABD
422	SAFEWAY #2	78		340				6			TRN						ABD
423	TOWN OF LEESBURG PL#2	78	D	320	506	49		6			TRN	57	12	205	.05	10	PUB
424	NOTRE DAME ACADEMY	79	D	495	205	45		6			PCMA	55	3	190	.01	2	INS
425	NOTRE DAME ACADEMY	78	D	470	605	8		6			PCMA	58	17	580	.02		INS
426	NOTRE DAME ACADEMY	79	D	480	415	46		6			PCMA	35	17	390	.04	3	INS
427	ALICE JACKSON	78	D	505	177	140		6	175	177	TRI	40	10			1	DOM
428	F WARREN	79	D	570	425	28		6			CPCC	42	4	400	.01	1	DOM
429	THOMAS HOLMES	78	D	550	260	10		6			PC	15	10				DOM
430	THOMAS B SHEDD	78	D	550	160			6			PC	20	25				DOM
431	R HUGH MCCAULEY	78	D	550	210	10		6			PC	20	25				DOM
432	PHILLIP J PRANG JR	79	D	550	145	20		6			PC	38	40	126	.31	1	DOM
433	OVERBROOK FARMS INC	79	D	620	145	40		6			PC	25	15	125	.12	1	DOM
434	SUE PULEO	79	D	485	305	38		6			PCMA	43	3	285	.01	1	DOM
435	LOUIS GIBB	78	D	495	605	15		6			CPCS	62	3	585		1	DOM
436	JERRY MICHAEL	78	D	350	500	20		6			TRI	40	7				DOM
437	GORDON D RUST	79	D	463	365	32		6	290	2910	PC	29	3	340			DOM
438	HAROLD B WILSON	79	D	465	510	5		6	503	504	PCMA	60	1			1	DOM
439	ASHLAND ACRES INV CO	79	D	233	225	52		6			TRI		24				DOM
440	JOE LESBURG	78	D	460	160	40		6			PCMA	50	12				DOM
441	ADM WILLIAM SMALL	79	D	375	165	17		6			PCMA	27	15	140	.10	1	DOM

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442	A C ECHOLS JR	79	D	660	530	12	6			PCMA	30	1	500		1	DOM
443	ALLEN DEV CO	79	D	410	300	52	6			PCMA	50	3				DOM
444	MARK RIFFLE	78	D	265	460	6	6	30		TRN	5	1				DOM
445	ROBERT D BASSFORD	78	D	500	340	27	6			PCMA	50	1				DOM
446	RICHARD O GORE	78	D	455	220	1	6	220		TRN	40	12				DOM
447	ALBERT ORRISON JR	78	D	430	560	100	6	400		TRN	80	40				DOM
448	LENA MORRIS	79	D	480	300	20	6	178	180	PCMA	15	4			2	DOM
449	ROGER ZYLSTRA	79	D	520	80	10	6	49	50	PCMA	15	25			1	DOM
500	JAMES BAGALY	79	D	495	120	10	6	100		CPCS	22	10			1	DOM

APPENDIX C

"Using Large Diameters to Increase Well Storage" *

You don't have to buy bottled water just because your well yields less than one gallon per mintue.

Even a ½ gpm well can provide a reserve of 720 gallons per day more than enough to supply a family of four for two days.

Some aquifers, such as "tight" shales or limestones, just aren't porous enough to permit prolonged pumping. Especially when local ground water conditions have not been adequately assessed, low yield wells may result. These will require some form of storage.

Storage system design requires an accurate estimate of present and future water needs. Ways to calculate water use requirements are described in "Planning for an Individual Water Supply," and "Water Systems Handbook," (Both available from the National Water Well Association). Light industry relying on low yields can forecast water requirements through process engineering studies.

Large diameter well storage

The best storage area for a reserve water supply is the well itself. Contractors can increase a wells' storage capacity simply by drilling larger diameters. Although water production capacity does not increase dramatically with well diameter, every added diameter inch radically increases storage capacity. (Table 1)

The table shows that a low yield well with 4-6" diameter could not supply a family of four requiring 200 gpd. Periods of heavy use would quickly dewater the well. An 8-inch well with

75 feet of water-filled casing would just meet this family's needs. Any well 10 inches in diameter or larger with 50 feet of water storage would exceed the family's requirements.

Keep in mind that water use is highly variable. In the consumer's best interest, drillers should suggest that casing storage capacities be at least 50 percent greater than apparent requirements.

Pressure tanks

Water system pressure tanks can also help provide storage. These tanks prevent rapid cycling of the pump motor, and provide additional pressurized water storage. Both of these functions are critical in increasing storage capacity of low yield wells.

An oversized pressure tank can be used to provide supplemental water storage. Tank drawdown is increased to meet the system's demands.

Proven well yield, pump capacity, maximum water requirements and operating pressure and pressure range numbers will determine pressure tank size. Storage capacity is usually only a fraction of total daily water use; and only 10 to 30 percent of the tank is full at a given time.

When peak usage rates exceed the well's capacity, a larger pressure tank can be used. An intermediate storage tank may be more appropriate if storage requirements exceed 700 gallons. In any case, the water system should be able to supply the peak use rate continuously for one hour in domestic systems, and two hours for light industrial and farm applications.

In some cases, both a large diameter well and an oversized pressure tank may be required. This combination would provide daily domestic needs from the pressure tank, and an emergency storage supply in the well casing.

Above ground non-pressurized tanks

Light industry and agriculture can also take advantage of well storage capacities. Required storage volumes are much larger than domestic applications: they should be able to meet water needs for 24 to 48 hours. Water supply wells must also yield more - 5 to 10 gpm for a 10,000 gallon storage tank is sufficient.

Since systems for light industry and agriculture must also provide water for uses at varying pressures, booster pumps and pressure tanks are used.

Water is pumped into the non-pressurized storage tank by the well pump. Pumping head is only required to overcome pipe friction loss and elevation between the pump and storage tank "full" level.

A float-level is used to control pump operation. The pump "on-off" range is usually 100 gallons. (After the float switch turns the pump off, 100 gallons of water must be drained from the tank before the pump will be reactivated.)

Water levels in a low yield well supplying such a storage system must be closely controlled. Solenoid activated pump switches attached to water level sensors in the well are used for this purpose.

The sensors are located at two levels in the well: the lower sensor a few inches above pump intake, and the upper one just below the well's minimum static water level. When water level drops past the lower sensor, a circuit is broken, activating the solenoid switch and turning off the pump. When the well recovers its natural static level, the upper sonsor resets the lower sensor circuit and starts the pump.

Control of pump motor speed is another way to prevent dewatering of low yield wells. Pump motors are allowed to pump only 85 percent of the wells' production capacity. Since it cannot pump more water than the well produces, the pump will not dewater the well.

Pump motors for low yield well systems must be continuous duty type, since the pump may be required to operate around the clock.

TABLE 1

			Volume of Water Storage In Water Filled Casing Length		
Nominal Casing Size	Inside Diameter	Storage per linear ft.	50' Section	75' Section	100' Section
4"	4.03"	0.66 gal	33 gal	49.5 gal	66 gal
5"	5.05"	1.04 gal	52 gal	78 gal	104 gal
6"	6.07"	1.50 gal	75 gal	113 gal	150 gal
8"	8.07"	2.66 gal	133 gal	200 gal	266 gal
10"	10.19"	4.24 gal	212 gal	318 gal	424 gal
12"	12.09"	5.96 gal	300 gal	447 gal	600 gal
14"	13.25"	7.16 gal	358 gal	537 gal	716 gal
15"	14.25"	8.29 gal	415 gal	622 gal	830 gal
16"	15.25"	9.49 gal	475 gal	712 gal	949 gal
18"	17.18"	12.05 gal	603 gal	904 gal	1206 gal
20"	19.18"	15.01 gal	751 gal	1126 gal	1501 gal

GLOSSARY OF TERMS

ACIDIC ROCKS:	A general descriptive term referring to igneous rocks which contain greater than 66 percent silica (SiO_2).
ALLUVIUM:	A general term for sediments deposited during recent geologic time by a stream or river.
AMYGDALOIDAL:	Describes volcanic rocks characterized by cavities formed by gas bubbles and subsequently filled with minerals differing from the rock mass.
ANTICLINE:	An arch or fold in rock strata that is convex upward.
AQUICLUDE:	A geologic formation which is not permeable enough to furnish an appreciable supply of water to a well or spring.
AQUIFER:	A geologic formation, group of formations, or part of a formation capable of supplying water to wells and springs in usable quantites. An aquifer is unconfined (water table) if the surface of the water table is at atmospheric pressure or confined (artesian) if the upper surface of the groundwater is under pressure in excess of atmospheric pressure due to the presence of an overlying, confining formation (aquiclude).
ARKOSE:	A granular sedimentary rock composed of large grains of quartz and feldspars from the disintegration of acidic rocks.

ARTESIAN SURFACE:	Level to which water will rise in a closed column due to hydraulic pressure.
AUGEN:	Refers to large mineral grains which have the shape of an eye.
AUGEN GNEISS:	A banded metamorphic rock characterized by the presence of large phenocrysts, "augen", of various minerals.
BASALT:	A dark, ferromagnesian-bearing igneous, extrusive rock.
BASE FLOW:	The flow of groundwater into a stream.
BASIC ROCKS:	A general term describing igneous rocks which are low in silica and relatively high in dark colored minerals.
BASEMENT:	Complex of crystalline igneous and metamorphic rocks which underlie the sedimentary sequence in any region and appear to have no other units below them.
BEDDING PLANE:	A plane surface separating layers in stratified rocks.
BEDROCK:	A solid rock exposed at the surface (outcrop) or overlain by unconsolidated materials.
BIOTITE:	A common black mineral of the mica group.
BOULDER:	A rock fragment greater than 256mm (10.08 inches) in diameter.
BRECCIA:	A rock composed of highly angular fragments often caused by crushing or movement along a fault.

CALCITE:	Calcium carbonate, a common mineral which occurs in cracks and cavities in rocks and as the main constituent of limestone.
CAMBRIAN:	A term used to describe a geologic age, 570-500 million years ago, and also those rocks which were formed during that period.
CASING:	Pipe, either metal, plastic, or in some cases cement, which is placed in a drilled hole to prevent the hole caving and to seal out surrounding contaminants.
CATCHMENT:	The area comprising the actual water intake area for aquifer recharge and all areas that contribute surface water to the intake area.
CHLORITE:	A sheet-like dark green mineral belonging to the mica group.
CLASTIC:	A term referring to rocks composed of fragments of pre-existing rocks.
CLAY PAN:	A layer of compacted but not cemented clay which is relatively impervious to water.
COBBLE:	A rock fragment with a diameter of between 64mm (2½ inches) and 256mm (10.08 inches). Often rounded from stream transport.
COLLUVIAL:	Unconsolidated masses of sediments that are gravity deposited.
CONE OF DEPRESSION:	The depression in the level of the water table caused by pumping water out of the aquifer. The depression usually takes the form of an inverted

cone around the point of withdrawal.

CONFINING LAYER: An impervious layer which restricts water to the aquifer in which the water is already present.

CONGLOMERATE: A rock composed of rounded fragments of pre-existing rock cemented together by another mineral.

COUNTRY ROCK: Refers to the rock into which an igneous (molten) mass intrudes.

CROSS BEDDING: Lineations or laminations within a layered sequence which are oblique to the direction of the main strata.

CRYSTALLINE ROCKS: Rocks whose constituent minerals have a definite recognizable crystal form.

DIABASE: A fine to medium grained dark colored rock similar in composition to basalt.

DIASTROPHISM: The earth movement process of mountain building.

DIKE: A tabular mass of igneous rock which cuts through adjacent rocks. Usually caused by the intrusion of a magma.

DIP: The angle between the surface of an inclined stratum and the horizontal plane.

DOLOMITE-MAGNESIUM CARBONATE: A common rock forming mineral similar in composition to limestone but containing magnesium and sometimes iron.

EPIDOTE: A pistachio-green calcium silicate mineral commonly found in metamorphic rocks.

EUGEOSYNCLINE: A large area formed as a geosyncline which contains volcanic material.

FACIES: A distinct unit of sedimentary rock distinguished from adjacent units by differences in lithology, fossil content, structure, etc.

FAULT: A plane of fracturing along which movement has taken place in some direction.

FEEDER DIKE: A smaller offshoot of a dike which shows the same cross cutting relationship and connects to the main dike.

FELDSPAR: Important rock forming minerals of the aluminum silicites.

FELSITE: A term given to an igneous rock consisting of extremely fine crystals of quartz and feldspars. Some larger crystals may be present.

FLUVIAL: River-deposited sediments.

FOLD: A curve or bend in rock strata.

FORMATION: An assemblage or rock masses grouped together into a unit that is convenient for description or mapping.

FRACTURE: Breaks in rocks due to intense folding or faulting.

FRAGIPAN: A resistant layer of clay with calcareous cement which is imperivous to water.

GABBRO: A deeply emplaced magmatic rock similar to granite, though darker.

GARNET: A mineral group which is often indicative of metamorphism.

GEANTICLINE: A broad uplifted section of the crust of the earth.

GEOHYDROLOGY: The science that relates geology and the water beneath the earth.

GEOSYNCLINE: A large syncline.

GNEISS: A metamorphic rock characterized by alternate bands of granular and platy or, more generally, light and dark minerals.

GPD: Gallons per day.

GPM: Gallons per minute.

GRANITE: A rock which forms below ground and consists of alkalic feldspars, quartz, and minor amounts of biotite, mica and other feldspars.

GRANULITE GNEISS: A high temperature, banded, metamorphic rock consisting of even-sized grains and containing mica and hornblende.

GRAYWACKE: A general term referring to a grayish rock composed of angular fragments of granular igneous in a clay-silica groundmass.

GREENSCHIST: Both a degree of metamorphism and a schistose green rock consisting primarily of chlorite.

GREENSTONE: A general term given to basic igneous rocks, such as basalt, which contain abundant chlorite, epidote and hornblende.

GROUNDMASS: The material surrounding the crystals and grains in a rock.

GROUNDWATER:	Water occurring in the zone of saturation beneath the land surface.
HYDRAULIC LIFT:	The difference between the top level of an artesian aquifer and the level to which a column of water will rise from this aquifer due to hydraulic pressure.
HYDROLOGY:	The science that relates to the water of the earth.
HYDROTHERMALLY ALTERED:	Refers to the processes whereby rocks and their constituent minerals are changed by exposure to mineral rich waters associated with magmas.
IGNEOUS:	Rocks or minerals that solidified from molten rock (magma).
IGNEOUS INTRUSION:	Refers to the forceful emplacement of molten rock into existing rock.
IMPERMEABLE:	Refers to a substance or strata which will not allow water to pass through it.
INTRUSIVE:	Refers to igneous rocks which have penetrated into or between older rocks while molten but have solidified before reaching the surface.
JOINT:	A fracture in rock along which no appreciable movement has occurred.
KAOLINITE:	A common aluminum silicate clay. Kaolin, a rock composed chiefly of kaolinite is used to make porcelain and china.
LITHOLOGY:	The composition and structure of rock.

LPM:	Liters per minute.
MAFIC:	Refers to ferro-magnesian minerals or, more generally, dark colored minerals.
MASS WASTING:	Refers to the movement of large rock or earth masses due to gravity.
METAMORPHIC:	Refers to any rocks derived from pre-existing rocks in reponse to pronounced changes of temperature, pressure, and chemical environment.
MICA:	Refers to a group of thin-sheetlike minerals which are an important constituent of many metamorphic rocks.
MIOGEOSYNCLINE:	A large geographic area formed from a syncline, but lacking volcanic materials.
MGD:	Million gallons per day.
MONZONITE:	A rock which contains orthoclase and plagioclase feldspars in roughly equal amounts. This rock forms below the ground surface and usually contains small amounts of quartz.
M.Y.B.P.:	Million Years Before Present.
NORMAL FAULT:	A fault in which the upthrown side of the fault does not overhang the downthrown side.
ORDOVICIAN:	A term used to describe a geologic age, 500-430 M.Y.B.P., and also those rocks which formed during that period.
OVERBURDEN:	Generally used to refer to all unconsolidated materials which overlie bedrock.

PALEOZOIC:	A geologic era which extends from 570 M.Y.B.P. to 225 M.Y.B.P.
PERCOLATION:	Movement of water through the interstices of rocks or soils except movement through large openings such as solution channels.
PERMEABILITY:	A measure of the ability of a rock, sediment or soil to transmit water.
PERVIOUS:	Refers to a material which will allow water to pass through it.
PHENOCRYST:	A large, distinct crystal in a finer grained groundmass.
PHYLLITE:	A micaceous metamorphic rock similar to slate, but lustrous.
POROSITY:	The property of a rock, soil, or other material of containing spaces or voids; the ratio of the void space to the total volume in a given sample of rock or soil, expressed as a percentage.
POTENTIOMETRIC SURFACE:	The level to which water will rise in a cased well; describes the water table surface or the artesian surface depending on the confining conditions of the aquifer.
PRECAMBRIAN:	Refers to a geologic age, prior to 570 M.Y.B.P., and those rocks which formed during that time.
PUBLIC SUPPLY:	As defined by the Virginia Department of Health, a water system serving 25 individuals or more than 15 residential connections.

PUMPING LEVEL:	Depth to water in a well when the well is being pumped.
PYROCLASTIC:	Rocks formed of volcanic debris, i.e., ash, cinders, bombs.
QUARTZ:	Silicon Dioxide (SiO_2). One of the most abundant rock forming minerals.
QUARTZITE:	A metamorphic rock consisting of greater than 95 percent quartz.
RECHARGE:	The addition of water to an aquifer by natural infiltration or artifical means.
RELIEF:	The difference in elevation between high and low points on the earth's surface.
RHYOLITE:	This igneous rock forms above ground and consists of silica and feldspar. Glass content (silica) is often very high.
RUNOFF:	That part of precipitation that appears in streams; includes surface runoff and groundwater flow that reaches streams. Groundwater runoff is a measure of the change in groundwater storage and indicates rate of groundwater recharge.
SAPROLITE:	Refers to weathered, highly decomposed rock.
SCHIST:	A metamorphic rock with somewhat-parallel grain-orientation giving a banded appearance by color or mineralization.
SEDIMENT:	Material borne and deposited by water, wind, or glaciers.

SEDIMENTARY: Refers to rocks formed from the consolidation of sediments.

SERICITE: Fine grained mica often found in schists; often appears to be a clay.

SHALE: A laminated sedimentary rock consisting primarily of compacted clay size grains.

SILT: An unconsolidated sediment whose grains range in size from 1/16mm to 1/256mm in diameter.

SLATE: A metamorphic rock characterized by distinct cleavage and fine grains.

STATIC LEVEL: Depth to water in a well when the well is not being pumped.

STRUCTURE: Refers to the physical features present in an area or in an individual rock.

SYENITE: An igneous rock which forms below ground and consists of feldspar and mafic minerals.

SYNCLINE: A fold in rock strata that is convex downward. Pertaining to, or designating the external earth forms resulting from deforming forces such as compression, tension, etc.

TALC: A very soft mineral used in talcum powder, insulators, etc.

TECTONIC: Refers to the processes and results associated with deformation of the earth's crust.

TERRACE: A level or gently inclined surface bordering a stream which represents a former level of the stream. Terraces are composed of alluvium produced by renewed downcutting of the flood plain or valley floor by the stream.

TEXTURE:	Physical aspects of a rock including grain size, shape, arrangement, etc.
TOPOGRAPHY:	The surficial aspects of an area, i.e., flat, rolling, hilly, etc.
TRIASSIC:	A term used to describe a geologic age, 195-225 M.Y.B.P., and also those rocks which were formed during that period.
TUFF:	A rock composed of small particles of volcanic debris which are welded together.
UNCONSOLIDATED:	A sediment that is loosely arranged or whose particles are not cemented together.
WATER TABLE:	The upper surface of the zone of rock or soil saturated with ground water.
WEATHERING:	A general term referring to the chemical and physical processes whereby rocks are broken down into smaller particles or basic minerals.

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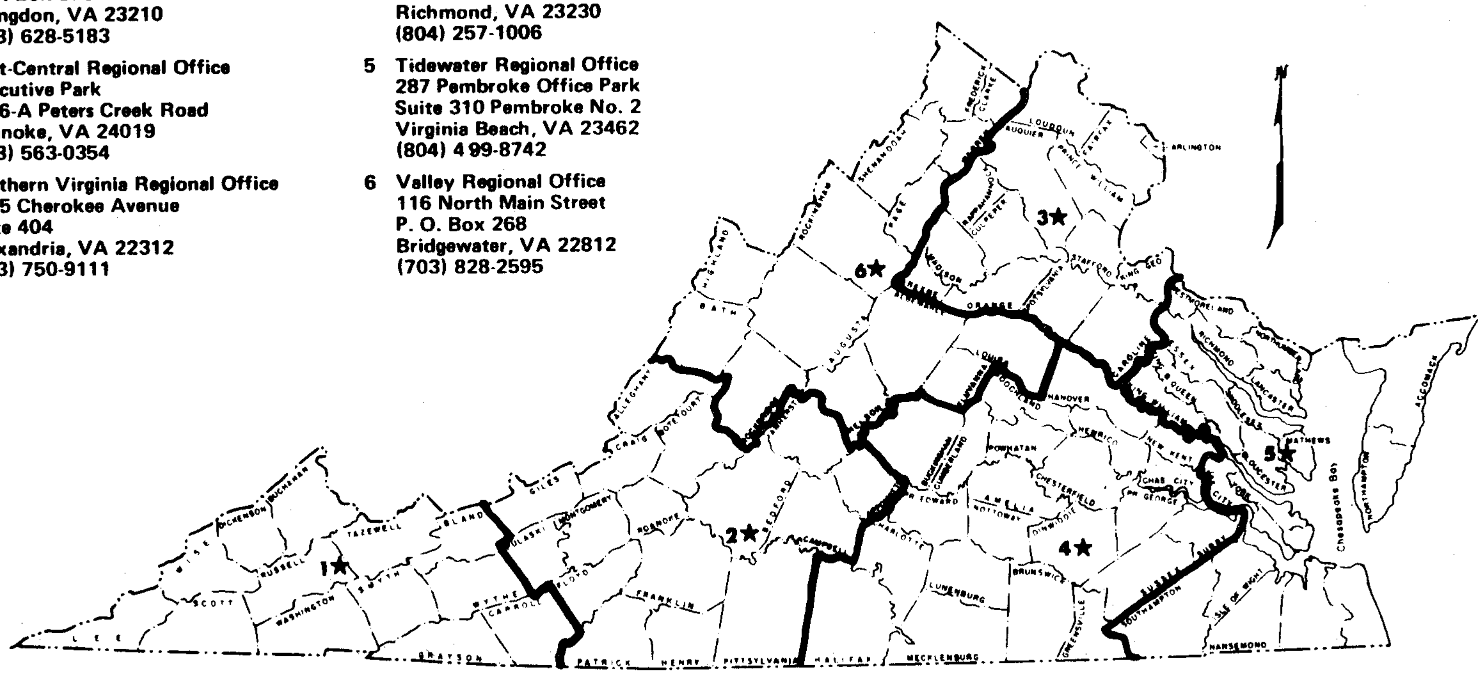

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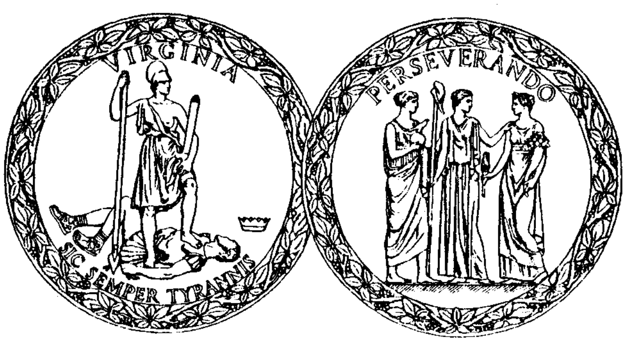
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